Energy Efficiency Trends in Canada

[1990 to 1994]

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and Analysis Division
Energy Efficiency Branch

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Energy Efficiency Indicators

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Minister's Foreword

The federal government is committed to the sustainable development and use of energy in Canada. To this end, Natural Resources Canada (NRCan) delivers programs to encourage and assist Canadians to make more efficient use of energy and to consider using alternatives to conventional energy sources. Are we making progress? To help answer this question, we need to understand how energy is used in Canada; how it is changing and why.

This document examines recent trends in end-use energy consumption in Canada. It identifies and analyses the factors which have caused changes in the demand for energy and develops indicators of energy efficiency improvements. It is the first such publication ever produced in Canada.

Considerable work and effort has gone into preparing this report. Understanding developments in energy efficiency requires detailed data on buildings, equipment and vehicles, and on the way in which they are used. A few years ago, much of this data was not available, in a consistent fashion, across Canada. Through its National Energy Use Database Initiative, NRCan has initiated new data surveys and has supported the consolidation of existing data at national centres located at five Canadian universities. Much progress has been made but more work is still to be done.

As Minister of NRCan, I recognize that a key to achieving goals and objectives is the establishment of sound monitoring and assessment systems. This report on energy efficiency trends and the accompanying publicly available database represent important components of the system for assessing progress in achieving sustainable development and in responding to concerns about global climate change. It will be updated annually and enhanced as the availability and quality of data is further improved.

A. Anne McLellan

A. Anne McLellan
Minister of Natural Resources

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Preface

This report is the first of a series of annual reviews of trends in end-use energy efficiency in Canada. The objective of these annual reviews is to track trends in energy efficiency and their contribution to changes in energy use and greenhouse gas emissions.

Chapter 1 of the report sets the context and the framework for the study and describes the relationship between energy use and carbon dioxide emissions. Chapter 2 reviews the influence of energy efficiency on secondary energy use. Chapters 3 through 6 take a detailed look at sector-by-sector trends in energy use over the last decade, with particular attention paid to the impact of energy efficiency. Chapter 7 focuses on changes in energy use in the four end-use sectors since 1990, which is the period that will be the focus of future annual reviews.

Appendix A presents the data used to prepare the graphs in the report. The sources of these data are not documented in the main body of the text, and the reader should consult Appendix A for this information.

Appendix B presents the methodology and data sources that underlie the analysis of factors influencing energy use (factorization analysis). Appendix C presents a reconciliation of the sectoral definitions used in the report with those found in our major sources of data, Statistics Canada's *Quarterly Report on Energy Supply and Demand.*

This report was prepared by staff of the Energy End-Use Analysis and Data Development Group, which is managed by Jean-Pierre Moisan. The project leader was Mark Pearson. Major contributors to the report were Michel Francoeur, Louise Métivier, Alain Paquet, Cristobal Miller and Maryse Courchesne. Nicholas Marty provided overall direction.

The report was prepared using a methodology and database developed by Informetrica Limited for Natural Resources Canada.

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Executive Summary

The objective of this report is to further the understanding of recent changes in energy efficiency in Canada. This will, in turn, assist policy makers in evaluating their responses to the issue of global climate change and sustainable development.

This report utilizes a factorization method to determine the contribution of energy efficiency to changes in end-use (i.e., secondary) energy use. The factorization method allows an assessment of the underlying changes in *energy intensity* for each end-use sector: residential, commercial, industrial and transportation. Through the factorization method, it is possible to disentangle the effect of changes in *energy intensity* on energy use from changes in economic growth (activity) and changes in the mix of energy-using products or activities (structure). These changes in *energy intensity* can be interpreted as "indicators" of changes in energy efficiency.

In 1992, Canada signed and ratified the Framework Convention on Climate Change. Under the Convention, Canada and other countries agreed to work toward stabilizing greenhouse gas emissions at 1990 levels by the year 2000. The National Action Program on Climate Change outlines the federal-provincial strategy for achieving this goal and provides guidance for action beyond the end of the century. A key element of this strategy is promoting greater energy efficiency in all sectors of the economy.

Trends in energy efficiency are presented for the period from 1984 to 1994, with a particular emphasis on the sub-period from 1990 to 1994. The year 1990 was chosen to coincide with the base year of Canada's environmental commitment, thus allowing trends in energy efficiency to be examined against environmental objectives. Future annual energy efficiency reviews will also use 1990 as the base year.

Changes in Secondary Energy Use 1984–1994 and 1990–1994

Secondary energy use, which accounts for about 70 per cent of the total energy requirements of the Canadian economy, increased by 995 petajoules (an average annual rate of 1.5 per cent per year) over the period 1984 to 1994. While there were significant declines in *energy intensity*, their effects were more than offset by strong growth in economic activity. Had all other factors affecting energy use remained constant at their 1984 levels and only activity changed in each sector, secondary energy use would have grown by 1576 petajoules. Conversely, if all factors except *energy intensity* had remained constant, energy use would have decreased by 467 petajoules.

Over the period from 1990 to 1994, growth in secondary energy use of 382 petajoules (1.3 per cent per year) was also mainly influenced by the competing factors: economic activity and *energy intensity*. Growth in economic activity alone would have led to an increase in secondary energy use of 492 petajoules. Changes in *energy intensity* alone would have led to a decline in secondary energy use by 123 petajoules.

Changes in Residential Energy Use 1984-1994 and 1990-1994

Residential energy use, which accounts for 19 per cent of secondary energy use, increased by 190 petajoules (an average annual rate of 1.5 per cent) over the period from 1984 to 1994. The change in residential energy use was largely influenced by growth in economic activity (the number of households), which increased at an average annual rate of 1.9 per cent, and to a lesser extent by the decline in *energy intensity*, which alone would have led to an average decline in energy use of 0.4 per cent per year. Weather had a slight impact on growth in energy use because 1984 was slightly colder than 1994.

The decline in *energy intensity* over the period 1984 to 1994, was largely the result of improvements in energy efficiency in space heating and appliances. For example,

- the efficiency mix of oil and natural gas heating equipment shifted from conventional units, which accounted for virtually all sales in 1984, to mid-and high-efficiency units which accounted for all sales in 1994;
- the efficiencies of new refrigerators and freezers improved by 53 per cent; and
- housing units built over the last two decades are better insulated and more airtight than older units.

The effect on energy use (an average annual decline of 1.1 per cent) due to changes in *energy intensity* over the period from 1990 to 1994 was the result of greater penetration of more energy-efficient equipment and houses.

Changes in Commercial Energy Use 1984-1994 and 1990-1994

Commercial energy use, which accounts for 13 per cent of secondary energy use, increased by 114 petajoules (an average annual rate of 1.3 per cent) over the period from 1984 to 1994. The change in commercial energy use was largely influenced by the offsetting factors: growth in economic activity (measured as the growth in floor area), which increased at an average annual rate of 3.5 per cent, and improvements in *energy intensity*, which alone would have led to an average decline in energy use of 2.1 per cent per year.

The decline in *energy intensity* over the period 1984 to 1994 was the result of changes in the energy efficiency of the buildings and the equipment they house, as well as the density of occupation of buildings and the behaviour of the occupants. Examples of energy efficiency trends over the last decade include the following:

- the efficiency of boilers and furnaces increased considerably over the last decade; through improvements, such as the addition of high-efficiency burners, space heating energy efficiency increased by up to 10 per cent;
- there is a trend towards the installation of more energy-efficient T-8 lighting systems, which were not commercially available in Canada in 1984 yet are now estimated to account for 75 to 95 per cent of sales related to retrofit of existing buildings and installation in new buildings; and
- the energy efficiency of space-cooling systems improved by about 25 per cent over the last decade as a result of technological upgrades, such as free-cooling economizers, thermal storage, energy-efficient compressors and fan and pump motors, and larger evaporator and condenser surfaces.

Over the period 1990 to 1994, the effect on commercial energy use due to changes in *energy intensity* was an average annual decline of 0.4 per cent. This decline resulted partly from the penetration of more energy-efficient buildings.

Changes in Industrial Energy Use 1984–1994 and 1990–1994

Industrial energy use, which accounts for 39 per cent of secondary energy use, increased by 391 petajoules (an average annual rate of 1.5 per cent) over the period from 1984 to 1994. The change in industrial energy use was largely influenced by the growth in economic activity (measured as gross domestic product), which increased at an average annual rate of 1.8 per cent.

Although the effect on energy use of declining *energy intensity* was modest (i.e., an average rate of 0.1 per cent per year), significant improvements in energy efficiency occurred over this period. Examples of these trends in energy efficiency were observed:

- in the iron and steel industry where there were shifts to the electric-arc furnace technology, which uses only about 13 per cent of the energy of an integrated mill, and from ingot casting to continuous casting, which can reduce the energy requirements of the casting process by 50 to 90 per cent;
- in aluminum production where old Soderberg-type smelters, which use 18 or 19 megawatt hours of electricity per tonne of aluminum, were replaced by more efficient smelters, which use as little as 14 megawatt hours per tonne;
- in the cement industry with the increased penetration of dry process cement production, which consumes only 3.6 to 4.5 gigajoules of energy per tonne of clinker compare to the wet process which uses between 5.0 and 6.0 gigajoules per tonne; and
- in the pulp and paper industry where there was a shift to mechanical pulping from chemical pulping, a process which uses about 20 per cent more energy than mechanical pulping.

From 1990 to 1994, the effect on industrial energy use due to changes in *energy intensity* was an average decline of 0.2 per cent per year. One industry that made significant energy efficiency improvements during this period is the smelting and refining industry (the fastest-growing sub-sector since 1990). In fact, the two most energy-efficient aluminum smelters currently in use began operating after 1990.

Changes in Transportation Energy Use 1984–1994 and 1990–1994

Transportation energy use, which accounts for almost 27 per cent of secondary energy use, includes two components: the energy used to move people – passenger transportation – and goods – freight transportation. This sector is divided into four mode segments: road, rail, air and marine.

Passenger transportation energy use, which accounts for a little more than two-thirds of transportation energy use, increased at an average annual rate of 1.5 per cent over the period from 1984 to 1994. This change was largely influenced by the offsetting factors: growth in economic activity (measured as passenger-kilometres), which increased at an average annual rate of 3.4 per cent, and improvements in *energy intensity*, which alone would have led to an average decline in energy use of 1.8 per cent per year.

Over the period 1984 to 1994, *energy intensity* declined in the light vehicles segment (cars and light trucks) of road passenger transport energy due to the penetration of more efficient vehicles into the vehicle stock. Between 1970 and 1984, the fuel efficiency of new small cars improved by 2.2 per cent per year, while the fuel efficiency of large cars and light trucks improved by 3.7 per cent per year.

Trends towards heavier and more powerful vehicles between 1984 and 1994 worked towards offsetting technological changes, resulting in only about a 2 per cent increase in fuel efficiency over this period. Examples of these technology changes include

- four- or six-cylinder engines and multi-point fuel injection;
- improved aerodynamics;
- front-wheel drive; and
- four-speed overdrive automatic transmissions.

Over the period 1990 to 1994, the effect on the light vehicles segment of passenger transportation energy use due to changes in *energy intensity* was a decline at an average rate of 2 per cent per year. This decline was also in response to the penetration of more fuel-efficient vehicles.

Energy Efficiency in Context

HIGHLIGHTS

- From 1984 to 1994, energy-related carbon dioxide emissions in Canada increased at an average annual rate of 1.3 per cent; secondary energy consumption increased at an average annual rate of 1.5 per cent. The lower rate of increase in emissions was the result of a decline in the share of fossil fuels (due primarily from a shift to nuclear) and a decline in the average carbon content of fossil fuels (reflecting a shift from coal and oil products to natural gas).
- From 1990 to 1994, energy-related carbon dioxide emissions and secondary energy use increased at average annual rates of 1.2 per cent and 1.3 per cent respectively. The lower rate of increase in emissions was the result of similar trends in the share of fossil fuels and the average carbon content of fossil fuels as experienced in the 1984 to 1994 period.

Energy use has been a matter of policy concern since the 1970s. Following the oil crises of 1973 and 1979, governments took major steps to promote energy conservation. This was done primarily to reduce reliance on imported oil. With energy prices being regulated below world levels, there was a recognition that the marketplace would be unable to produce the required energy efficiency improvements.

By the mid-1980s, the world oil "shortages" had turned into world oil "gluts." Governments deregulated energy prices and markets and phased out most of the programs to promote energy conservation. It was felt that the marketplace, left alone, would produce the optimal level of energy efficiency improvements.

By the end of the 1980s, however, concerns were beginning to arise about the impacts on the atmosphere of burning fossil fuels, such as coal, oil and natural gas. In particular, there was growing worldwide concern about energy use and associated greenhouse gas emissions and their implications in global climate change.

In 1992, Canada signed and ratified the Framework Convention on Climate Change. Under the Convention, Canada and other countries agreed to work to stabilize greenhouse gas emissions at 1990 levels by the year 2000. The National Action Program on Climate Change outlines the federal-provincial strategy for achieving this goal and provides guidance for action beyond the end of the century. A key element of this strategy is promoting greater energy efficiency in all sectors of the economy. Since 1990, governments at all levels in Canada have introduced or enhanced programs to reduce the market barriers to energy efficiency and to accelerate the development and adoption of more energy-efficient technologies.

The objective of this report is to further the understanding of recent changes in energy efficiency in Canada. This will, in turn, assist policy makers in evaluating their responses to the issue of global climate change.

The report examines trends in secondary energy use, sector by sector, over the past 10 years.[1] A detailed assessment is important, since many of the actions taken to limit greenhouse gas emissions are aimed at energy use in specific end uses (e.g., appliances, cars, building components, industrial processes). The report places a major emphasis on separating energy efficiency changes from other factors affecting energy use, such as changes in activity or structure.

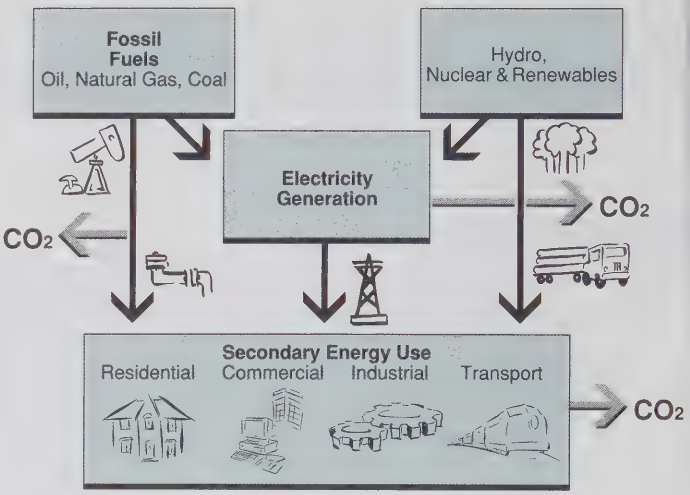
This chapter takes a brief look at the relationship between secondary energy use and carbon dioxide emissions.[2] It will then explain the framework used to analyze the major factors, including changes in energy efficiency, which have influenced secondary energy use over the past 10 years. The remaining chapters of this report describe the results of the analysis. Chapter 7 focuses on the period from 1990 to 1994. Updates to this report will be published annually, focusing on the period from 1990.

1.1 Secondary Energy Use and Carbon Dioxide Emissions

There is a close relationship between changes in secondary energy use and changes in carbon dioxide emissions from energy use. The relationship, however, is not always constant. This is because there are other factors that are also important.

Figure 1.1 shows how energy use results in carbon dioxide emissions. In addition to changes in *secondary* energy use, the following factors affect carbon dioxide emissions:

Figure 1.1
The Relationship Between Secondary Energy Use and Carbon Dioxide Emissions



Changes in the efficiency of energy production, transmission and distribution

Most energy sources require processing, conversion and transportation before they are ready for end-use consumption. The energy used along the way is the difference between primary energy and secondary energy. A decrease in the ratio of *primary to secondary energy use* caused, for example, by an improvement in electrical generation efficiency, will lead, all other things being equal, to lower carbon dioxide emissions.

Changes in the balance between fossil fuels and non-fossil fuels

Carbon dioxide emissions are the result of burning fossil fuels such as coal, oil and natural gas. They do not result from consumption of non-fossil energy sources such as nuclear power and most renewables.[3] The ratio of *fossil energy use to primary energy* measures how much primary

[1] The time period of analysis in this report is from 1984 to 1994. While data on energy use and other variables analyzed in the report are available for many years prior to 1984, two considerations influenced the choice of this period. First, there was a desire to compare results for each sector; this could only be done by choosing a common period. Second, given the first requirement, the base and end years had to be the same. The choice of the end year was directed by the availability of the most recent actual data (1994); the choice of the base year pointed to the earliest year for which data were available on an on-going basis for all end-use sectors. As to the latter, the residential sector database became the binding constraint, since at the time of writing, NRCan's Residential End-Use Model Database had only been calibrated back to the year 1984.

[2] This report does not focus on total greenhouse gas emissions. Since the focus of the report is energy use, only energy-related greenhouse gas emissions are relevant to the discussion. We have chosen to use energy-related carbon dioxide emissions as a proxy for total energy-related greenhouse gas emissions. Energy-related carbon dioxide emissions account for approximately 90 per cent of total energy related greenhouse gas emissions.

[3] Renewables, such as hydro, wind and solar, do not generate emissions. The burning of wood emits carbon dioxide, but growing trees absorb carbon dioxide emissions. Whether there is a net increase in emissions will depend on whether new trees are planted to offset those burned as fuel.

energy is supplied by fossil fuels. Thus, for example, a shift from coal to nuclear or wind electricity generation will lead to a decrease in the ratio of fossil energy to total primary energy and, all other things equal, to a decrease in carbon dioxide emissions.

Changes in the balance among fossil fuels

Not all fossil fuels produce the same level of carbon dioxide (CO_2) emissions when burned. Coal produces more CO_2 emissions than oil and oil more than natural gas. The ratio of *carbon dioxide emissions to primary fossil energy* is a measure of the average carbon content of the fossil fuel mix in primary energy use. A decrease in this ratio, for example, due to a shift from coal to natural gas, will lead, all other things being equal, to a decrease in carbon dioxide emissions.

All of the above factors can either offset or reinforce the impact of changes in secondary energy use on carbon dioxide emissions. It is crucial to recognize this when assessing the role and the effectiveness of energy efficiency in mitigating climate change.

From 1984 to 1994, energy-related carbon dioxide emissions (CO_2) in Canada increased at an average annual rate of 1.3 per cent. Secondary energy use (secondary) increased at an average annual rate of 1.5 per cent over this period. Figure 1.2 shows the relationship between the two trends.

The ratio of *primary to secondary energy* (Primary/Secondary) increased at an average annual rate of 0.67 percent from 1984 to 1994. This factor on its own would have caused an increase in carbon dioxide emissions. However, the fact that the major source of the increase in primary energy was the growth in non-fossil fuel energy sources offset the impact on emissions of growth in the ratio of *primary to secondary energy.*

The ratio of *fossil energy to primary energy use* (Fossil/Primary) declined at an average rate of 0.7 per cent per year, as the use of renewables – hydro and nuclear energy sources – increased more than that of fossil fuels. A large part of this change was due to the increased use of nuclear energy in the generation of electricity.

The ratio of *carbon dioxide emissions to primary fossil energy* (CO_2/Fossil), or the average carbon content of fossil fuels, decreased at an average annual rate of 0.14 per cent over the period, mostly as a result of a shift from coal and oil products to natural gas. Thus, the net result was an increase in carbon dioxide emissions that was only slightly lower than the increase in secondary energy consumption.

Figure 1.2
Factors Influencing Growth in Carbon Dioxide Emissions, 1984-1994 (average annual growth rate – per cent)

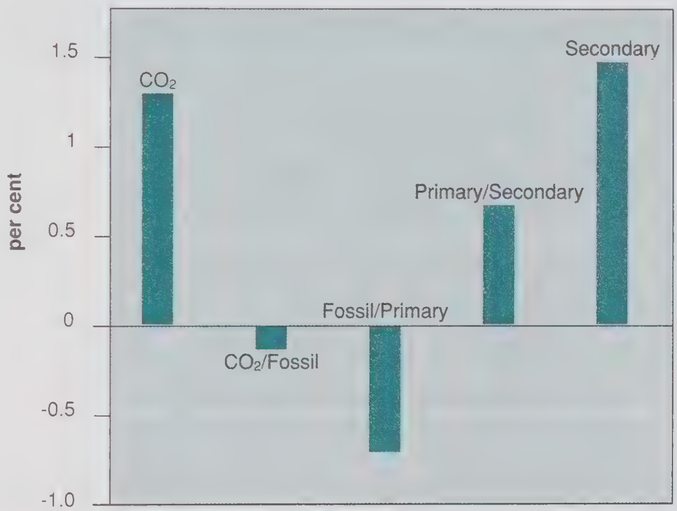
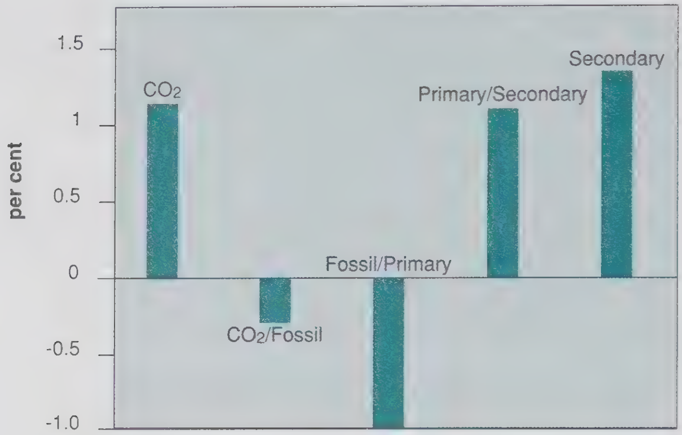


Figure 1.3 presents a similar story for 1990 to 1994. The order of magnitude of the average annual rate of change in carbon dioxide emissions and secondary energy use is similar to that of the period from 1984 to 1994. In both periods, the average growth in secondary energy use is slightly higher than that for carbon dioxide emissions, as the impacts of the three other factors, while significant individually, offset each other.

Figure 1.3
Factors Influencing Growth in Carbon Dioxide Emissions, 1990 - 1994 (average annual growth rate – per cent)



1.2 Framework for Assessing the Impact of End-use Energy Efficiency on Secondary Energy Use

A major challenge in assessing changes in secondary energy use is determining the extent to which they reflect improvements in energy efficiency. To get insight into this, we have adopted the energy efficiency indicators method.

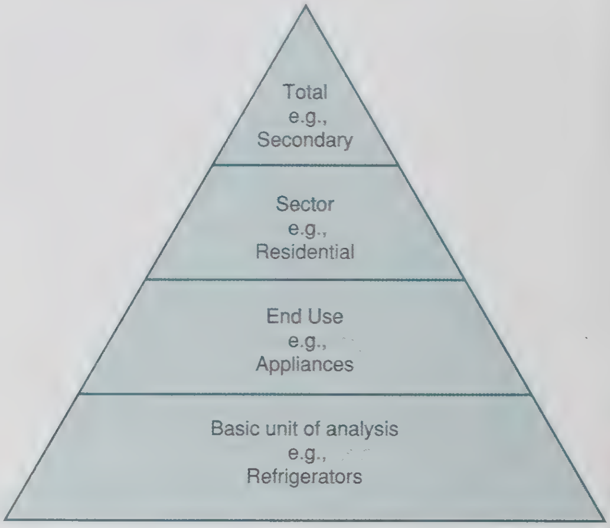
During the past 20 years, a large body of research has accumulated on energy efficiency indicators. Much of this research was done by organizations such as the Lawrence Berkeley Laboratory in the United States and the Agence de l'environnement et de la maîtrise de l'énergie in France (Ademe).[4] We have adopted two of the most useful tools developed through their work: the indicators pyramid and the factorization method.

The indicators pyramid[5] is illustrated for the residential sector in Figure 1.4. Indicator pyramids for other sectors are presented in Appendix B.

The pyramid shows the differing levels of aggregation at which secondary energy consumption can be analyzed and at which indicators of efficiency can be developed.

Thus at the top level, one can examine residential energy use and assess aggregate sector-specific indicators, such as residential energy use per household. Or, one can look at the energy use associated with the different categories of service being provided and examine such indicators as appliance energy use per household or heating energy use per household. At the most disaggregated level, one can examine indicators related to specific pieces of equipment, such as energy use per unit of output of a refrigerator.

Figure 1.4
The Indicators Pyramid: A Residential Sector Illustration



It is only really possible to measure energy efficiency for specific pieces of equipment. More aggregated indicators measure energy intensity. They represent a mixture of factors including energy efficiency. For example, one house may consume more energy per square metre than another house, yet it will be better insulated and have more energy-efficient appliances and

[4] Schipper, L., Myers, S., Howarth, R. and Steiner, R.: *Energy Efficiency and Human Activity: Past Trends and Future Prospects*. Cambridge University Press, Cambridge, Great Britain, 1992. Ademe, *Cross Country Comparison on Energy Efficiency Indicators: Phase 1*, Paris, France, November 1994.

[5] Lawrence Berkeley Laboratory, *International Comparisons of Energy Efficiency: Establishing a Framework for International Cooperation and Research*, Berkeley, California, March 1994.

heating and cooling equipment. This could be because it has more energy-using products, a different mix of products, or because it has different operational requirements (e.g., room temperature may have to be kept at a high level all day because there is always someone at home).

This report presents data on energy use at various levels of disaggregation. It is not always possible to provide information at the most disaggregated level due to data limitations, particularly for commercial and industrial energy use where there is a large variety of energy-using equipment (see box "THE PYRAMID VERSUS DATA NEEDS"). At each level of disaggregation, we isolate energy efficiency or energy intensity changes from the other factors influencing energy use. This is done through the factorization method.

THE PYRAMID VERSUS DATA NEEDS

The data requirements of the energy efficiency indicator method is highly demanding. In order to pursue reviews of this type and further the understanding of energy use at greater levels of detail, an established process for the collection of these data is essential. Natural Resources Canada's National Energy Use Database Initiative (NEUD) offers Canadians such an opportunity.

The NEUD was launched in October 1991 with the objective of improving knowledge about energy consumption at the end-use level. The rationale for the NEUD is simple: By improving our understanding of where and how energy is used in Canada, the database will reveal opportunities to improve energy efficiency, as well as provide the information required to track progress on the energy efficiency front.

To date, a number of surveys have been undertaken in most end-use sectors under the umbrella of the NEUD. In addition, a network of Data and Analysis Centres (five) have been created with each Centre specializing in a specific area of energy use. These two components of the NEUD will ensure that future reviews of energy efficiency trends are increasingly revealing. More information on the activities of the NEUD is available on request.

The methodological underpinnings of the factorization method are described in detail in Appendix B. Through this approach, it is possible to separate the effect on energy use of *energy intensity* changes from changes in *activity* and *structure*.

Level of Activity

Increases in population and in economic growth lead to a greater demand for goods and services. Producing and consuming more goods and services, all other things being equal, results in an increase in energy consumption. In subsequent chapters, we have used the following measures of activity:

- the number of households in the residential sector;
- floor space in the commercial sector;
- gross domestic product in the industrial sector;
- passenger-kilometres for passenger transport; and
- tonne-kilometres for freight transport.

Structure

Changes in the distribution of energy-using products or activities (i.e., *structure)* will affect energy use. For example, a shift in production from energy-intensive industries to industries using less energy will, other things being equal, result in a decline in energy consumption.

By estimating the importance of the above factors, it is possible to measure the effects that changes in *energy intensity* are having on energy consumption and the extent to which such changes are offset or reinforced by other developments. The estimated change in *energy intensity* is an "indicator" of changes in energy efficiency, although, as explained above, it is necessary to move to the most disaggregated level of energy use to obtain a complete understanding of what is happening.

1.3 Bringing It All Together

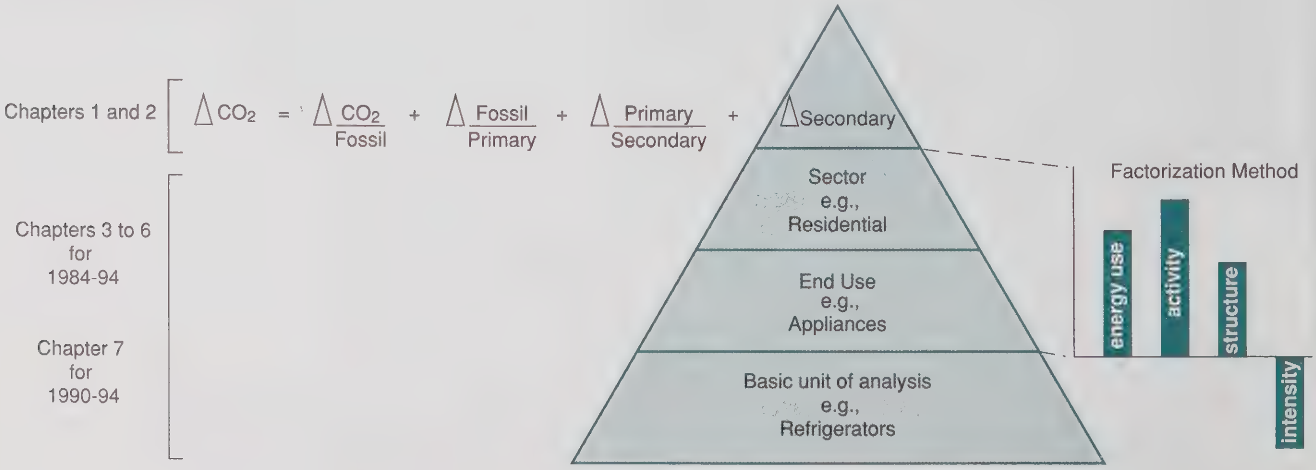
Figure 1.5 illustrates how the "indicator pyramid" discussed in section 1.2 relates back to the changes in energy-related carbon dioxide emissions discussed in section 1.1.

The equation at the top of the chart shows the factors which influence the growth in energy-related carbon dioxide emissions. The change in secondary energy consumption is a major factor but there are other important influences, such as the average carbon dioxide content of the fossil fuels mix (CO_2/Fossil), the mix of fossil fuels and non-fossil fuels (Fossil/Primary), and the efficiency of energy production, transmission and distribution (Primary/Secondary). The significance of these other influences were examined briefly in section 1.1.

The focus of the report is on determining the contribution of energy efficiency (the object of many initiatives to limit the growth in greenhouse gas emissions) to changes in secondary energy consumption. Since energy efficiency can only be measured at the "micro" level (e.g., the energy efficiency of a refrigerator or a furnace), a major disaggregation of energy use is required, as illustrated by the "pyramid" (shown in this example for only the residential sector). At various levels of disaggregation, the factorization method is used to isolate changes in energy intensity (e.g., energy use per household) from changes in activity (e.g., number of households) and structure (e.g., mix of houses and apartments). These changes in energy intensity can be interpreted as "indicators" of changes in energy efficiency (the latter is only directly measurable at the greatest level of disaggregation).

Chapter 2 takes a look at total secondary energy use for the period from 1984 to 1994, assessing the underlying changes in energy intensity. Chapters 3 though 6 do the same for each of the end-use sectors: residential, commercial, industrial and transportation. Chapter 7 examines total and sectoral energy use and underlying energy-intensity trends for the period from 1990 to 1994. Many more indicators were calculated for this project than are discussed in the report; all of the indicators calculated are presented in a public database available on request.

Figure 1.5
The Framework at a Glance



Chapter 2

Economy-Wide Trends in End-Use Energy Efficiency

HIGHLIGHTS

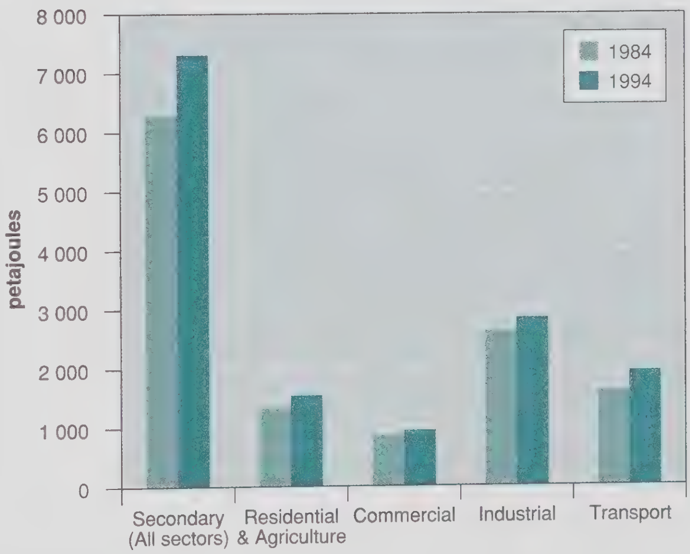
- From 1984 to 1994, secondary energy use increased at an average annual rate of 1.5 per cent. As a result, energy use was 995 petajoules higher in 1994 than in 1984.
- The change in secondary energy use over the last decade was largely influenced by growth in activity levels in each sector. Had all other factors remained constant over the period and only activity changed, secondary energy use would have increased by 1576 petajoules.
- Energy intensity declined in all end-use sectors, due in part to the significant improvements in the efficiency of energy use in the Canadian economy. This trend contributed to offset some of the influence of growth in activity on secondary energy use. Had only energy intensity changed over the period and other factors remained constant, energy use would have decreased by 467 petajoules.
- Shifts in the structure of each end-use sector and weather variations had minimal impact on the difference in secondary energy use between 1984 to 1994.

Secondary energy use accounts for about 70 per cent of the total energy requirements, i.e., primary energy, of the Canadian economy. At the secondary level, energy is consumed in four major sectors: the residential and agriculture, commercial, industrial and transportation sectors.

Figure 2.1 presents the distribution of secondary energy use by sector in 1984 and 1994. Over this period, secondary energy use increased from 6319 petajoules to 7314 petajoules, an average annual rate of 1.5 per cent.

The average annual increase in each sector varied little – from a low of 1.3 per cent in the commercial sector to a high of 1.5 per cent in residential. Industrial energy use accounted for the largest share (39 per cent) of the absolute increase in secondary energy use, as a result of the importance of industrial energy use as a component of secondary energy use.

Figure 2.1
Secondary Energy Use by Sector, 1984 and 1994 (petajoules)



2.1 Factors Influencing Growth in Secondary Energy Use Over the Last Decade

As noted in Chapter 1, the method of analysis developed for this report attributes impacts on energy use to three factors: *activity, structure* and *energy intensity*. The effect of *weather* is also examined in the analysis of residential and commercial sector energy use. Table 2.1 summarizes the impact of changes in each of these factors over the 1984 to 1994 period.[1]

A fifth factor, the *interaction* effect is also identified in Table 2.1. This factor results from the interaction between the four other factors. The box titled "THE INTERACTION EFFECT", on page 9, illustrates the relationships that lead to the calculation of this effect. The dimension of the interaction effect is presented throughout the report at all levels of analysis, but, for reasons alluded to in the attached box, no efforts were made to analyze its significance at this time. Such analysis will be the subject of further research to be discussed in future editions of *Energy Efficiency Trends in Canada.*

The results presented in Table 2.1 are an aggregation of the end-use sector-specific analyses that are discussed in the next four chapters. These results clearly show that over the period from 1984 to 1994, growth in *activity* levels was the predominant influence on secondary energy use. Changes in *activity* far outweighed the influence of changes in *structure, weather* and *energy intensity* on energy use over this period.

The measure of *activity* that underlies the factorization of energy use is different for each end-use sector: households are used in the

Table 2.1
Factors Influencing Growth in Secondary Energy Use, 1984 - 1994 (petajoules)

SECTOR	Energy Use 1984	1994	1994 less 1984 (d)	Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction	Other
Residential	1 202	1 392	190	246.9	0.3	7.8	-54.2	-10.4	n.a.
Commercial	823	936	114	337.1	7.5	0.4	-165.9	-65.5	n.a.
Industrial	2 450	2 841	391	489.5	-53.6	n.a.	-29.1	-15.9	n.a.
Transportation	1 677	1 949	273	502.8	54.1	n.a.	-218.1	-79.8	16
Passenger (a)	1 099	1 269	171	424.1	6.2	n.a.	-178.2	-76.1	-4
Freight (b)	578	680	102	78.7	48.0	n.a.	-39.9	-3.7	20
Agriculture (c)	167	195	28	n.a.	n.a.	n.a.	n.a.	n.a.	28
Total	6 319	7 314	995	1 576	8	8	-467	-172	44

(a) The factorization excludes the non-airline (commercial/institutional and public administration) air sector. The difference in energy use for this component is shown in the "Other" column.

(b) The factorization excludes the marine freight sector. The difference in energy use for this component is shown in the "Other" column.

(c) The factorization analysis was not done for the agriculture sector. The difference in energy use for this component is shown in the "Other" column.

(d) The difference in energy use between 1984 and 1994 and the sum of the activity, structure, weather and energy intensity effects for passenger and freight transport are slightly different because of i) the exclusion from the factorization analysis of the marine segment in freight transport and the non-airline segment in passenger transport and ii) the fact that the factorization of energy use for these sectors was done using motor gasoline equivalency values (see Chapter 6 footnotes for more detail). The same differences are found at the secondary energy use level in addition to the difference due to the exclusion of agriculture from the factorization.

[1] Table 2.1 presents results for all the sectors to which the factorization method was applied. This method was not applied to the agriculture sector; nor was it applied to the non-airline (i.e., commercial/institutional and public administration) air sector and the marine transport sector. The level and change in energy use for these sectors is included in the "Other" sector category in Table 2.1, and no impacts on energy use are attributed to activity, weather and intensity for this segment.

residential sector, floor space in the commercial sector, gross domestic product in the industrial sector, passenger-kilometres in passenger transport and tonne-kilometres for freight transport. As shown in the *activity* effect column of Table 2.1, had all other factors remained constant and only *activity* changed in each sector, secondary energy use would have grown by 1576 petajoules (i.e., an average annual rate of 2.3 per cent) rather than by 995 petajoules.

In general, structural shifts had minimal impact on the change in secondary energy use. As for activity, *structure* is measured differently in each end-use sector. In the residential sector, we refer to *structure* as the mix of activity by end use. In the commercial sector, we refer to it as the mix of activity by building type. In the industrial sector, we refer to *structure* as the mix of activity by industry. In both the passenger and the freight transport sectors, we refer to *structure* as the mix of activity by mode. Had all other factors remained constant and only *structure* changed in each sector, secondary energy use would have grown by 8 petajoules.

The difference in weather between 1984 and 1994, a factor which mostly affects space heating energy requirements in the residential and commercial sectors, had a small impact on the change in secondary energy use. Had all other factors remained constant and only *weather* changed, secondary energy use would have increased by 8 petajoules.

The increase in secondary energy use was moderated by declines in *energy intensity* in all end-use sectors. The reasons underlying changes in energy intensity are many and are different between each end-use sector. For example, in the residential sector, the past decade brought significant energy-efficiency gains, while in the passenger transport sector such gains were mostly achieved in the years preceding the decade under study (however, the vehicle stock turnover – i.e., the penetration of new vehicles that are much more efficient than the average stock – has had a significant impact on *energy-intensity* changes from 1984 to 1994). Had only *energy intensity* changed in each end-use sector over the last decade, energy use would have declined by 467 petajoules or an average rate of decline of 0.8 per cent per year.

THE INTERACTION EFFECT

The method used in this report to analyze the contribution to changes in energy use of growth in activity, structural shifts and energy intensity is a Laspeyres index method. One characteristic of this method is the estimation of an interaction effect. This effect exists as a result of the interdependence between the three main factors. The technical underpinnings of the interaction effect are presented in Appendix B.

Although the method used in the report attributes impacts on energy use to the factors – activity, structure, weather, energy intensity, and their interaction – the following example illustrates in simple terms the relationships that lead to the interaction effect for two factors. The data used are hypothetical:

	year 1	year 2	% change
1. Energy use	10	13	30
2. Activity	5	5.5	10
3. Energy intensity(1./2.)	2	2.36	18.2

The sum of the activity and energy intensity impacts is 28.2 per cent. This is 1.8 per cent short of the total change in energy use (30 per cent) that is being explained.

In this example, the 30 per cent change in energy use can be attributed as follows:

Activity:	10 per cent
Energy intensity:	18.2 per cent
Interaction:	1.8 per cent

While this is an oversimplification of the interaction effect calculation, it illustrates the basic principle that underlies it.

Many past studies have used different approaches to calculate the influence of activity and intensity on energy use. In some of these methods (e.g., Divisia index) the interaction effect is reallocated to activity and intensity arbitrarily, under the assumption that it is negligible.

We have chosen to present the interaction effect separately and have found that the assumption of it being negligible is not always valid. Further research efforts will be required to better understand this factor.

Chapter 3

Energy Efficiency Trends in the Residential Sector

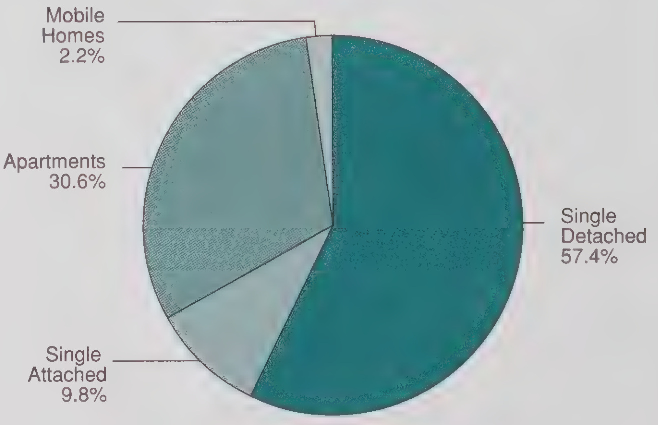
HIGHLIGHTS

- From 1984 to 1994, residential sector energy use increased at an average annual rate of 1.5 per cent. As a result, energy use was 190 petajoules higher in 1994 than in 1984.
- The growth in residential energy use over the last decade was largely influenced by two offsetting factors: economic activity and energy intensity.
- From 1984 to 1994, residential sector activity (measured as the growth in households) increased at an average annual rate of 1.9 per cent. Had all other factors remained constant over the period and only activity changed, residential sector energy use would have increased by 247 petajoules.
- Over the same period, energy intensity, largely influenced by improvements in the energy efficiency of houses and household equipment, declined at an average annual rate of 0.4 per cent. This change offset a large part of the influence of activity on energy use. Had all other factors remained constant over the period and only energy intensity changed, residential sector energy use would have decreased by 54 petajoules.

The residential[1] sector includes four major types of dwellings: single detached, single attached, apartments, and mobile homes. Energy is used in Canadian dwellings for space heating and cooling, water heating, and operating appliances.

Figure 3.1 shows that the category of single detached dwellings accounts for the largest proportion of households[2] (57 per cent). Apartments represent the second largest type (31 per cent), followed by single attached dwellings (10 per cent) and mobile homes (2 per cent).

Figure 3.1
Distribution of Households by Type of Dwelling in 1994 (per cent)



10 414 households ('000)

[1] This chapter addresses only the residential sector, exclusive of agriculture. See footnote 1 in Chapter 2. In 1994, residential energy use amounted to 1392 petajoules; the addition of agriculture energy use would bring the amount up to 1587 petajoules.

[2] Statistics Canada recently benchmarked the number of households to 1991 Census data. The benchmarking led to revisions in the number of households reported by Statistics Canada. These revisions have not been incorporated in this report.

3.1 Patterns of Energy Use in Households

Figure 3.2 illustrates the distribution of residential energy use by dwelling type. Similar to the distribution of households by dwelling, single detached dwellings account for the largest share (almost two-thirds) of residential energy use, followed by apartments (24 per cent), single attached dwellings (9 per cent), and mobile homes (2 per cent).

Figure 3.2
Distribution of Residential Energy Use by Type of Dwelling in 1994 (per cent)

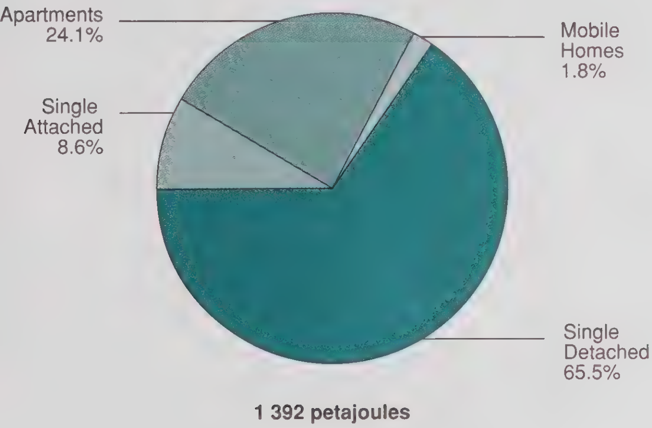


Figure 3.3 illustrates the distribution of fuel use in the residential sector. Natural gas is the fuel used most, accounting for 47 per cent of total energy use. Natural gas is used primarily for space heating and water heating. Electricity, which is used to meet all end uses, accounts for a little more than one third of total residential energy use. Oil accounts for 12 per cent of residential energy use.

Figure 3.3
Distribution of Residential Energy Use by Fuel in 1994 (per cent)

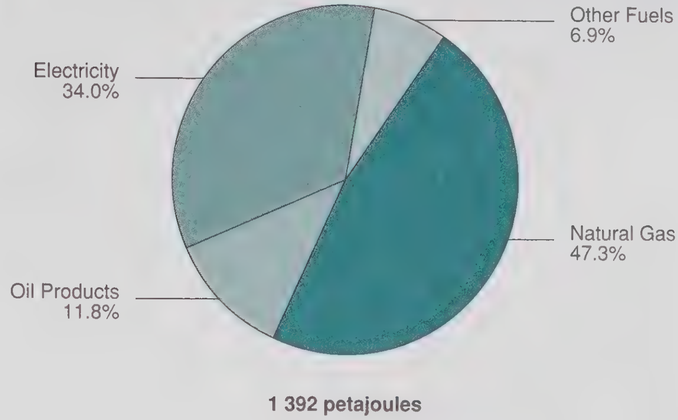
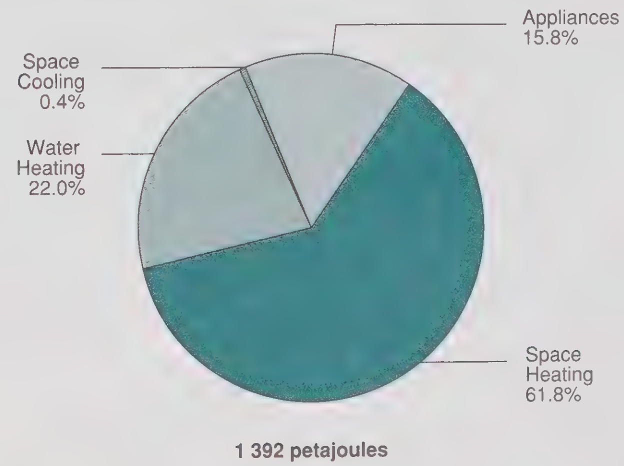


Figure 3.4 illustrates the distribution of residential energy use by end-use category for 1994. Space heating is the most important end use, accounting for 62 per cent of total residential energy use. Water heating also accounts for a considerable share of residential energy use, 22 per cent, followed by appliances, 16 per cent. Space cooling accounts for less than one per cent of residential energy use.

Figure 3.4
Distribution of Residential Energy Use by End Use in 1994 (per cent)

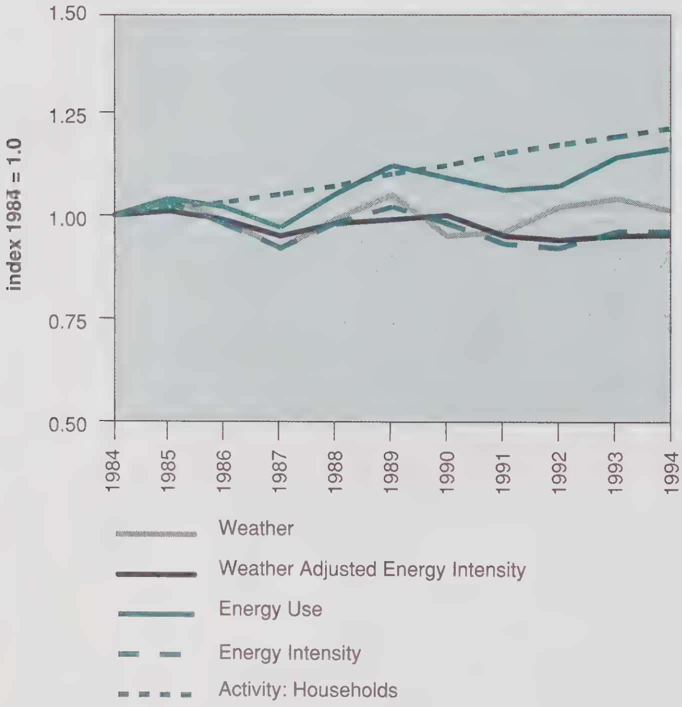


3.2 Trends in Residential Energy Use Over the Last Decade

Since 1984, residential energy use has increased by approximately 16 per cent: an average rise of 1.5 per cent per year. Over this period strong growth in residential sector activity, 21 per cent (or an average annual increase of 1.9 per cent) was softened by a 4 per cent (or 0.4 per cent per year) decline in energy intensity. Figure 3.5 illustrates the evolution of residential energy use, intensity (excluding the impact of weather), and activity over the period from 1984 to 1994.

Figure 3.5 also shows the trend in weather, which helps explain the fluctuations in energy use over the period. An index value greater than 1 indicates the weather was colder than in 1984, whereas an index value less than 1 indicates the weather was warmer than in 1984.

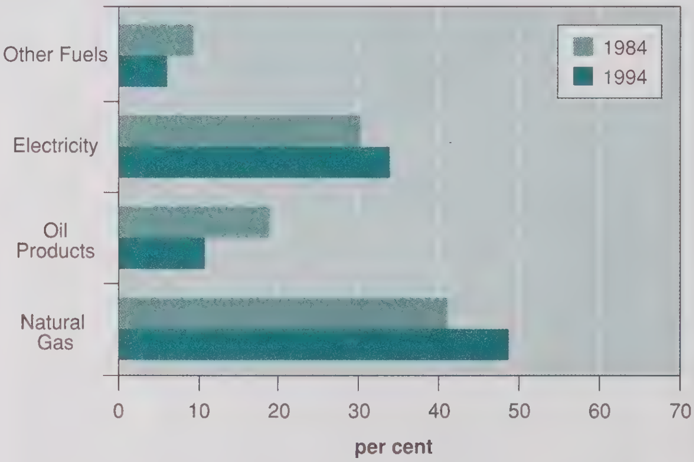
Figure 3.5
Residential Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)



It is apparent from the data in Figure 3.5 that the trend in residential energy use from 1984 to 1994 was strongly influenced by the trend in activity. Year-to-year variations in energy use, on the other hand, appear closely correlated with changes in weather and energy intensity.

Over the last decade, the distribution of fuel use in the residential sector has changed considerably. Figure 3.6 illustrates these changes. The most notable changes over this period concerned the shift away from oil, which decreased 6 percentage points, to natural gas, which increased 5 percentage points, and electricity, which increased 4 percentage points. The shift away from oil was precipitated by rapid oil price increases, pre-1986, and by government initiatives, such as the Canadian Oil Substitution Program (COSP).[3]

Figure 3.6
Residential Energy Fuel Shares, 1984 and 1994 (per cent)



Over the period, the share of natural gas increased 7 percentage points for space heating and 4 percentage points for water heating. These increases were largely in response to oil substitution, wider availability of natural gas and lower natural gas prices.

The growth in the share of electricity was predominant in both space heating and appliances. The use of electricity for space heating increased

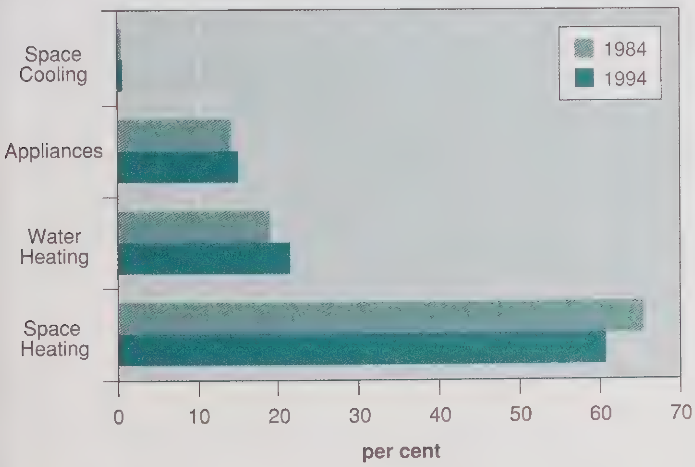
[3] COSP was a federal assistance program operated from October 1980 to March 1985. Under COSP, residential buildings were eligible for grants to convert oil heating equipment to the use of other fuels.

4 percentage points from 1984 to 1994. Electricity use for appliances increased by 24 per cent over the same period, as a result of greater penetration of appliances in Canadian homes.

Figure 3.7 illustrates the end-use shares for 1984 and 1994. Although it continues to be the single largest end use, the share of space heating decreased by almost 5 percentage points over the last decade. This decrease can be explained by energy efficiency improvements in heating equipment and housing construction and retrofit, as well as the increasing share of energy use for appliances.

Water heating and appliances increased their end-use shares over the 1984-1994 period, in response to increased penetration of appliances, including hot-water-using appliances – dishwashers and clothes washers. For example, the penetration of dishwashers increased 11 percentage points over this period.

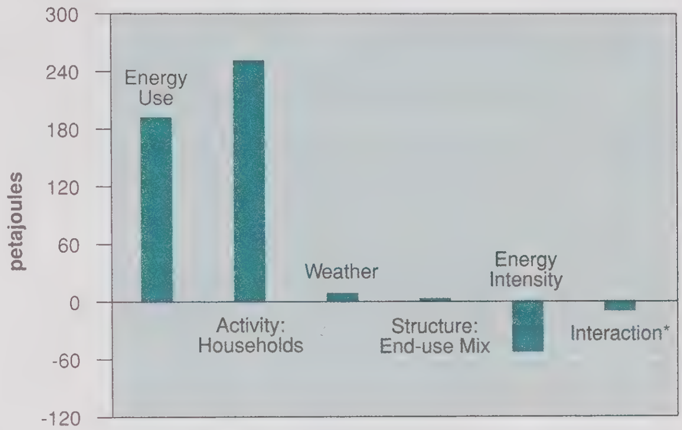
Figure 3.7
Residential Energy End-use Shares, 1984 and 1994 (per cent)



3.2.1 Factors influencing growth in residential energy use

Figure 3.8 illustrates the source of growth in total residential energy use from 1984 to 1994. The level of *activity* (measured as the number of households) had a significant impact on energy use during this period. In fact, had all other factors – *energy intensity, weather* and *structure* – except *activity* remained constant at their 1984 levels, then residential energy use would have increased by 247 petajoules, rather than the observed 190 petajoules from 1984 to 1994.

Figure 3.8
Factors Influencing Growth in Residential Energy Use, 1984-1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

The structure (measured as the end-use composition of activity) of residential energy use changed very little between 1984 and 1994. For example, all houses continued to use equipment for space heating, water heating and appliances. Although the proportion of households requiring space cooling increased from 17 per cent to 27 per cent, the relative share of energy use required for space cooling was so small that it had a negligible effect at the aggregate end-use level.

Weather had a slight impact on growth in energy use (8 petajoules) because 1994 was slightly colder than 1984.

The most important decrease (about 54 petajoules) in residential energy use was due to the change in *energy intensity*.

The rest of this chapter examines the relationship between residential energy use and energy efficiency at the end-use level.

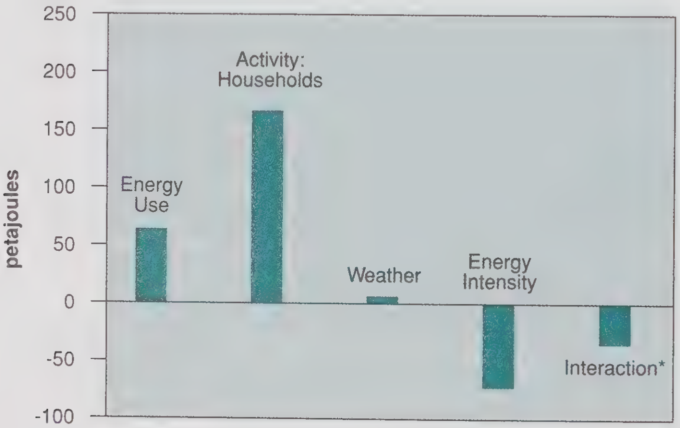
3.2.2 Factors influencing the use of energy to meet end uses in the home

Space heating

In the period from 1984 to 1994, energy demand for space heating increased by 64 petajoules (see Figure 3.9). This increase can be largely attributed to the growth in *activity* (measured as the number of households). Had all factors, except activity, affecting space-heating energy use remained constant from 1984 to 1994, space heating energy use would have increased by 164 petajoules.

Figure 3.9[4] shows that the increase in space heating energy use due to activity was offset by changes in *energy intensity.* Had all factors affecting space-heating energy use except *energy intensity* remained constant from 1984 to 1994, space heating energy use would have decreased by 72 petajoules.

Figure 3.9
Factors Influencing Growth in Residential Space Heating Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

In the period from 1984 to 1994, space heating *energy intensity* was affected by improvements in the efficiency mix of heating equipment, improvements in the thermal requirements for new and existing houses, increases in heated living area and decreases in the size of households. The rest of this section reviews these developments.

Changes in the efficiency mix of new equipment

During the last 10 years, the efficiency mix of heating equipment has changed significantly, putting downward pressure on space-heating energy use. In fact, if this change had not occurred, space heating energy use would have increased by an additional 40 petajoules. The change in the efficiency mix reflects a shift in oil and natural gas heating equipment from normal efficiency (i.e., annual fuel-utilization efficiencies [AFUE] of between 60 and 65 per cent) to mid-efficiency (78 to 83 per cent efficiency) and high efficiency (90 per cent or more). For example, in the early 1980s, normal-efficiency furnaces and boilers accounted for virtually all sales of oil and gas heating equipment. By 1994, normal-efficiency units had been eliminated from the market, leaving only mid- and high-efficiency units for sale in Canada.[5]

Evolution of energy efficiency in new housing

An important factor affecting energy use in the residential sector is the introduction of new, more energy-efficient housing. As indicated in the accompanying box, "THERMAL ENVELOPE CHARACTERISTICS OF NEW HOUSING BY PERIOD OF CONSTRUCTION", the thermal efficiencies of new housing, as measured in terms of resistance values (R-Values), have increased.

[4] At this detailed level of end-use disaggregation it is difficult to identify a structural effect. In this regard, structure is not addressed for space heating.

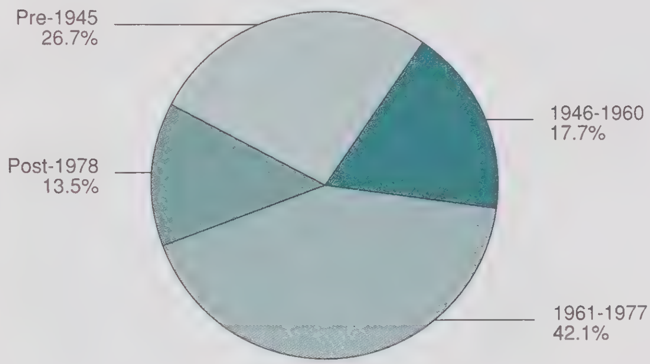
[5] Canadian Gas Association, *Canadian Gas Facts 1995,* North York, Ontario, September 1995. Geddes Enterprises, *Oil Fired Furnaces and Boilers Energy Performance Study*, Bramalea, Ontario, March 1994.

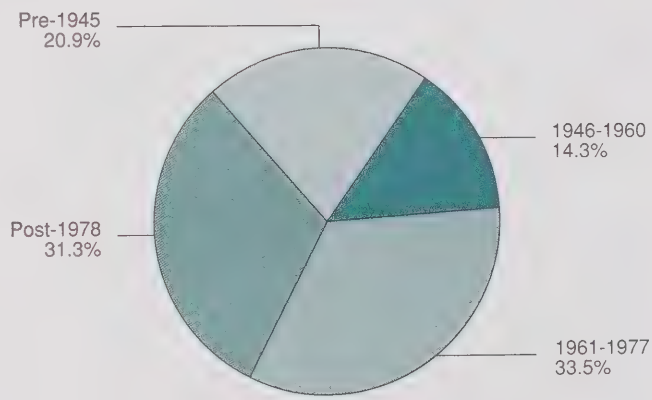
THERMAL ENVELOPE CHARACTERISTICS OF NEW HOUSING BY PERIOD OF CONSTRUCTION[6] (Insulation R-values)

	Ceiling	Wall	Basement
• Pre-1945 Wood-frame construction, ceiling insulation only	10	0	0
• 1945–1960 2 x 4 wood construction, ceiling and wall insulation	12	10	0
• 1961–1977 2 x 4 construction, insulation required by building codes	20	12	5
• 1978–1983 2 x 6 construction, more insulation, air and vapour barriers	30	20	10
• 1984–1994 More stringent building codes	33	20	12

Figure 3.10 shows that the proportion of older homes (pre-1960) decreased from almost 45 per cent in 1984 to 35 per cent in 1994. Meanwhile, the proportion of newer homes (built between 1978 and 1994) increased from 13 per cent in 1984 to 31 per cent in 1994. In this regard, the increase in the share of newer, more energy-efficient housing has helped reduce overall energy intensity.

Figure 3.10
Housing Stock by Vintage, 1984 and 1994 (per cent)





In response to the implementation of energy efficiency measures in building codes, housing units built since the late 1970s tend to be better insulated and more airtight than older units. This trend was observed in the results of the *1993 Survey of Household Energy Use* (*SHEU*)[7] which found that houses built after 1978 have less air leakage than older houses. When asked if they felt there were any air leaks or drafts around their windows, 73 per cent of *SHEU* respondents who owned houses built during or after 1978 answered "no". Fifty-nine per cent of respondents who owned pre-1978-built houses felt there were no air leaks from windows. Similar responses were found for air leakage associated with doors. Sixty per cent of *SHEU* respondents who owned newer houses felt there was no air leakage around doors, compared with 50 per cent of owners of houses built prior to 1978.

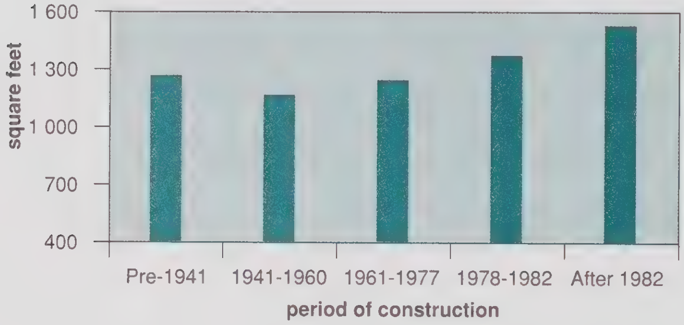
[6] Peat Marwick Stevenson and Kellog, *The Economically Attractive Potential for Energy Efficiency Gains in Canada*, May 1991.

[7] Natural Resources Canada, *1993 Survey of Household Energy Use*, Ottawa, Ontario, November 1994.

The size of new houses

SHEU data show a trend toward larger houses (See Figure 3.11). For example, the average heated living space of houses built after 1982 is 1535 square feet, compared with 1374 square feet for units built between 1978 and 1982, and 1287 square feet for units built between 1961 and 1977. Although increases in heated living space directly contribute to increasing energy use, energy efficiency improvements have more than offset these increases.

Figure 3.11
Average Heated Living Area per Dwelling by Vintage in 1993 (square feet)



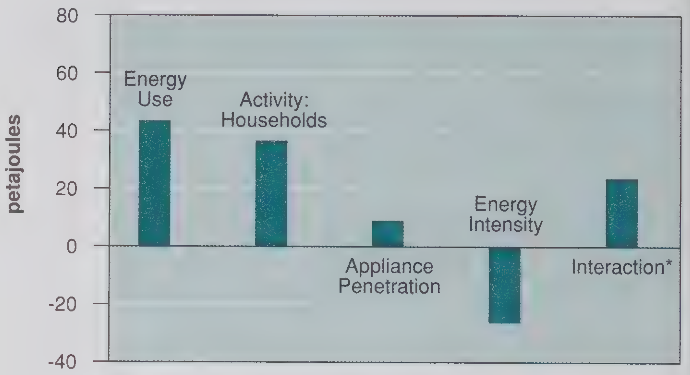
The size of households

The size of households, measured in terms of persons per household, decreased by 5 per cent over the period 1984 to 1994 (from 2.97 persons per household in 1984 to 2.81 in 1994).[8] Although marginal, the decrease in household size contributed to mitigating the increase in energy use for space heating as well as other end uses.

Appliances

Energy used by appliances increased by 42 petajoules from 1984 to 1994. Figure 3.12 shows the factors that influenced this increase.

Figure 3.12
Factors Influencing Growth in Residential Appliance Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

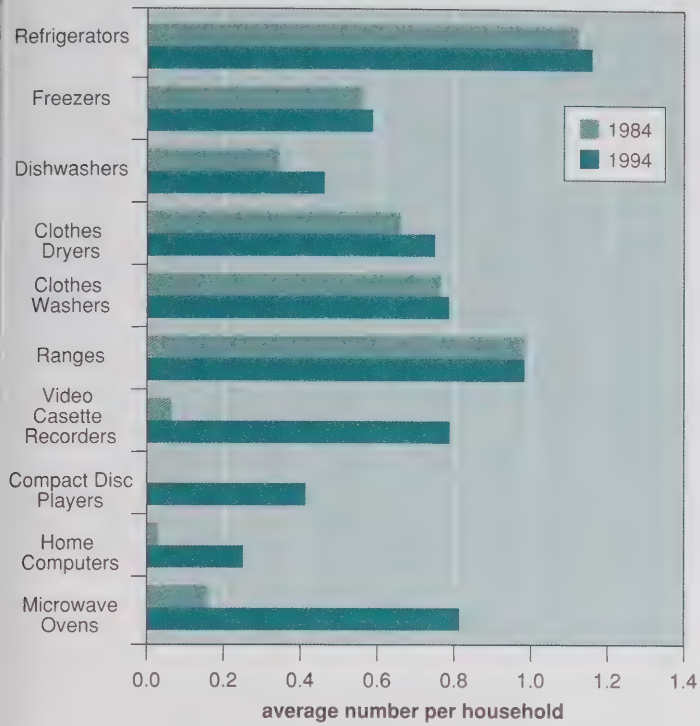
The increase in appliance energy use can be explained by growth of two factors. The first factor, activity (the number of households), put upward pressure on appliance energy use by about 37 petajoules.

The second factor, the penetration of appliances, impacted appliance energy use by about 9 petajoules. Strong growth in real disposable income per household over the 1980s stimulated an increase in the penetration of appliances.

Figure 3.13 illustrates the penetration rates of ten appliances for the years 1984 and 1994. The most significant increases for major appliances – refrigerators, freezers, dishwashers, clothes dryers, clothes washers and ranges – concerned dishwashers and clothes dryers. Dishwashers increased in penetration from 35 per cent of households in 1984 to 46 per cent in 1994, while clothes dryers increased 8 percentage points. Although to a lesser extent, freezers, refrigerators and clothes washers have also become more common over the period from 1984 to 1994.

[8] Statistics Canada, *Household Facilities and Equipment* (Catalogue No. 64-202), Ottawa, Ontario, October 1995.

Figure 3.13
Penetration Rates for Household Appliances, 1984 and 1994 (average number per household)



During the last decade, new technologies have continued to penetrate the Canadian market. Among these recent market entrants, microwave ovens showed the largest increase from 1984 to 1994. In 1984, only 16 per cent of Canadian households had a microwave oven. By 1994, microwave ovens were present in 81 per cent of all households.[9]

The number of households with compact disc players in 1984 was not reported. By 1994, 41 per cent of households had compact disc players.[10]

Only 13 per cent of households had video cassette recorders in 1984; by 1994, that proportion had increased to almost 80 per cent.

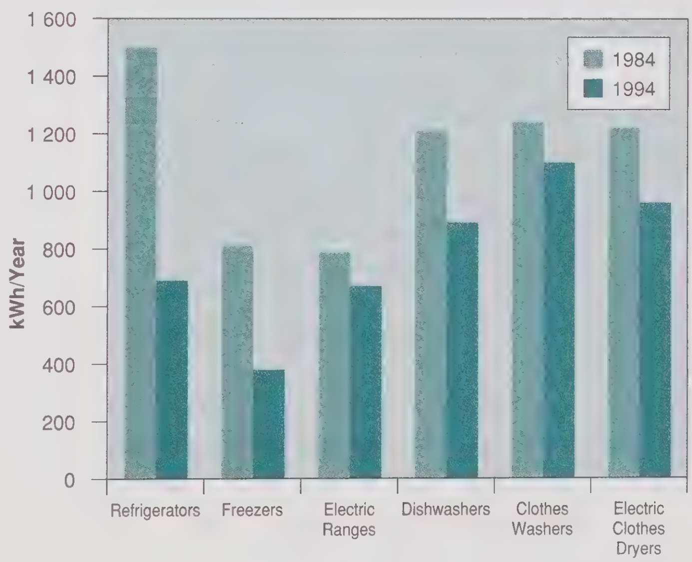
There has also been rapid growth in home computers. The saturation rate of home computers increased from 3 per cent of households in 1984 to 25 per cent in 1994.

The total unit energy use per household for three of these products – microwave ovens, video cassette recorders, and home computers – is greater than 400 kilowatt hours per year[11] per household, which is more energy than that required to operate a new freezer.

More efficient appliances

The increase in energy use associated with appliances was partially offset by substantial improvements in their energy efficiency, thus decreasing intensity. In this regard, more efficient appliances have led to a decline in appliance energy intensity of about 28 petajoules. Figure 3.14 illustrates the change in efficiencies for major new appliances between 1984 and 1994. Since the early 1980s, new refrigerators and freezers have become substantially more energy efficient. By 1994, the average new refrigerator and freezer were 53 per cent more efficient than their 1984 counterparts (see box "ENERGY EFFICIENCY TRENDS FOR REFRIGERATORS", page 18).

Figure 3.14
Energy Efficiency Trends of Appliances, 1984 and 1994 (kWh per year)



9 It is not clear that microwave ovens lead to a significant increase in energy used for cooking. It is clear that defrosting frozen foods in microwave ovens increases the energy used for cooking. However, using a microwave oven instead of a range or oven to cook food can lead to less energy use because microwave ovens are more energy efficient.

10 Similar to microwave ovens, compact disc players may not lead to an increase in energy use if they are used as a substitute for older audio equipment (e.g., turntables).

11 Estimate from Leo Rainer, Steve Greenberg, and Alan Meier, *The Miscellaneous Energy Use in Homes*, Procs. *1990 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Washington, D.C.

ENERGY EFFICIENCY TRENDS FOR REFRIGERATORS

The average unit energy consumption (UEC) of typical new refrigerators decreased 53 per cent from 1984 to 1994. Over the same decade, the size of refrigerators, a factor contributing to energy consumption, increased by 16 per cent. Therefore, the gains in efficiency associated with technology improvements have more than offset the increase in energy consumption associated with size.

NEW REFRIGERATOR 1984	NEW REFRIGERATOR 1994
Two-door with top-mounted freezer	Two-door with top-mounted freezer
Automatic defrost	Automatic defrost
15.4 cubic feet	17.9 cubic feet
UEC = 1 457 kWh/year	UEC = 690 kWh/year

Technology Improvements between 1984 and 1994

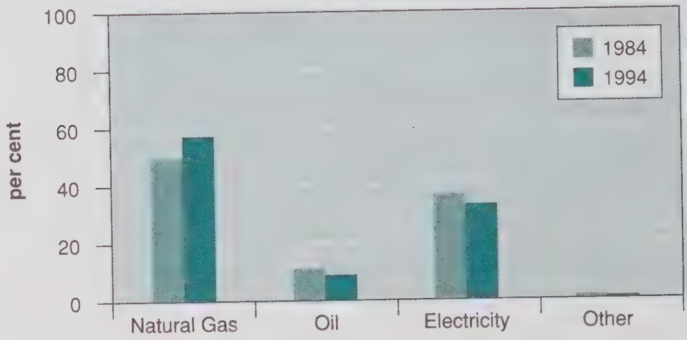
- More efficient compressor
- Foam insulation
- Better fan and motor
- Thicker insulation

Water heating

Water is heated for bathing (showers and baths), clothes washing, dishwashing, and other sink uses. The energy used to heat water increased by approximately 3 per cent per year from 1984 to 1994. Much of this increase can be explained by the increase in the number of households. In addition, more households now have two water-using appliances: dishwashers and clothes washers.[12] The most notable increase, 31 per cent (shown in Figure 3.13), was in the number of dishwashers. Fuel use was another factor contributing to the increase in water-heating energy use.

Figure 3.15 shows that the trend is leading away from oil and electricity toward natural gas. This trend has led to an increase in energy use because the technical efficiencies of electrical water heaters are significantly greater than those of oil and gas.

Figure 3.15
Distribution of Households by Water Heating Fuel, 1984 and 1994
(per cent)



The increase in water-heating energy use has been partially offset by efficiency improvements. For example, in 1994, new dishwashers were 26 per cent more efficient than those of 1984, and new clothes washers were almost 10 per cent more efficient (see Figure 3.14). Furthermore, improvements in the average technical efficiencies of new water heaters have led to increased efficiencies of 2 to 5 per cent for electric, gas and oil water heaters.

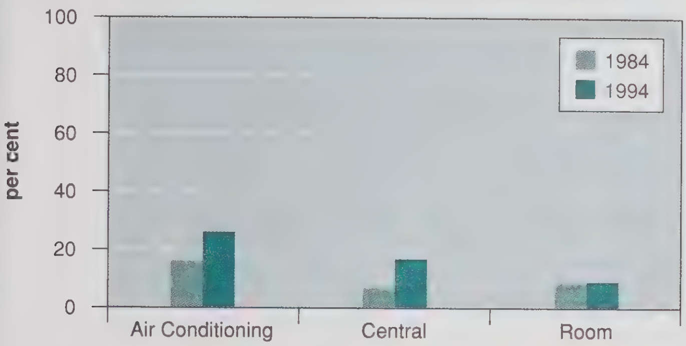
12 Approximately 88 per cent of the energy used by dishwashers and 92 per cent of the energy used by clothes washers is used to heat the water; the remaining energy is used by motors.

Space cooling

Energy used in space cooling accounts for less than 1 per cent of total residential energy use. However, air conditioners are becoming more common in Canada.

Figure 3.16 illustrates that the penetration rate of air conditioners increased from 17 per cent of households in 1984 to 27 per cent in 1994. This increase was largely attributable to central air conditioners, which more than doubled in penetration during this period.

Figure 3.16
Penetration Rates for Air Conditioners, 1984 and 1994
(per cent of households)



Air conditioning units became significantly more energy efficient between 1984 and 1994. For example, the energy efficiency of new room air conditioners increased 20 per cent[13] over the period.

[13] Association of Home Appliance Manufacturers, *Room Air Conditioners: Energy Efficiency and Consumption Trends,* Chicago, Illinois, July 1995.

Chapter 4

Energy Efficiency Trends in the Commercial Sector

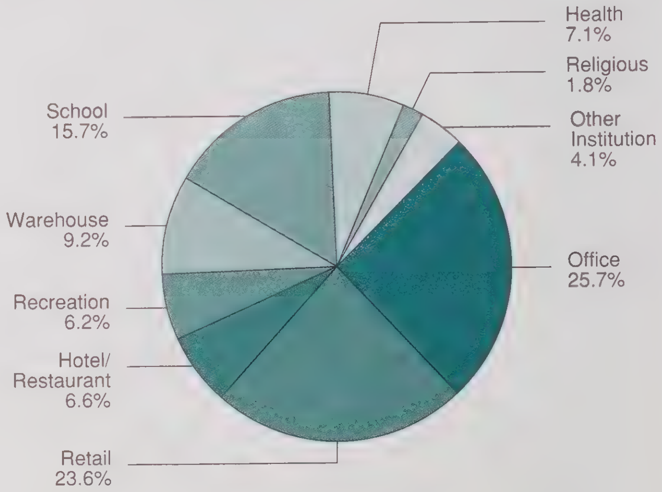
HIGHLIGHTS

- From 1984 to 1994, commercial sector energy use increased at an average annual rate of 1.3 per cent. As a result, energy use was 114 petajoules higher in 1994 than in 1984.
- The growth in commercial sector energy use over the last decade was largely influenced by two offsetting factors: economic activity and energy intensity.
- From 1984 to 1994, commercial sector activity (measured as floor area) increased at an average annual rate of 3.5 per cent. Had all other factors remained constant over the period and only activity changed, commercial sector energy use would have increased by almost 340 petajoules.
- Over the same period, energy intensity, largely influenced by improvements in energy efficiency, declined at an average annual rate of 2.1 per cent. This change offset a large part of the influence of activity on energy use. Had all other factors remained constant over the period and only energy intensity changed, commercial sector energy use would have decreased by 166 petajoules; in other words, without the decline in energy intensity, commercial sector energy use would have increased by about 280 petajoules.

The commercial sector is defined to include activity related to trade, finance, real estate services, public administration, education and commercial services (including tourism). In this sector, energy is mainly used to provide space and water heating, space cooling, lighting and motive power for services like pumping and ventilation.

The commercial sector comprises two major building types: commercial and institutional. Commercial buildings include offices, retail stores, restaurants, and other buildings devoted to commercial and service activities. Institutional buildings include schools, colleges, universities, hospitals and religious establishments.

Figure 4.1
Distribution of Commercial Floor Space by Building Type in 1994 (per cent)



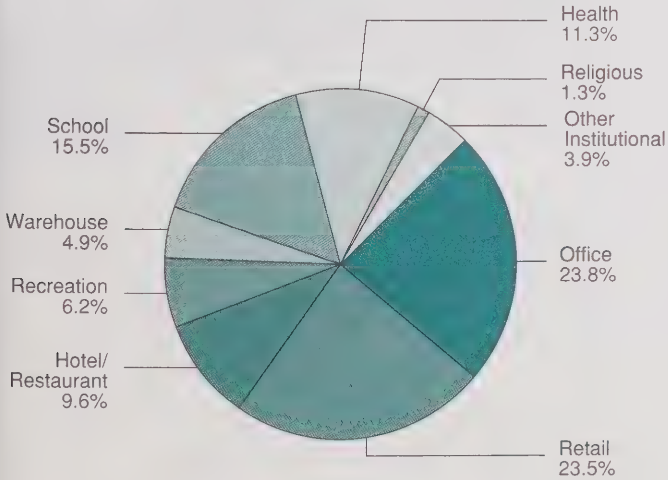
484 million square metres

Figure 4.1 shows that commercial buildings account for the largest share of floor area in the sector (71 per cent). Within this category, the most important sub-sectors are office buildings (26 per cent of commercial sector floor space) and retail (24 per cent). Among institutional buildings, schools are the most important, accounting for 16 per cent of total commercial sector floor area.

4.1 Patterns of Energy Use in Commercial Buildings

Figure 4.2 shows that the distribution of energy use by building type mirrors the distribution of floor area. Retail and office buildings together account for 47 per cent of the sector's energy use compared to 49 per cent of floor area. The share of energy use accounted for by hotels and restaurants (10 per cent) and health facilities (11 per cent) is significantly higher than the share of floor area (both 7 per cent) accounted for by these types of buildings – a reflection of the specific types of services rendered in these facilities.

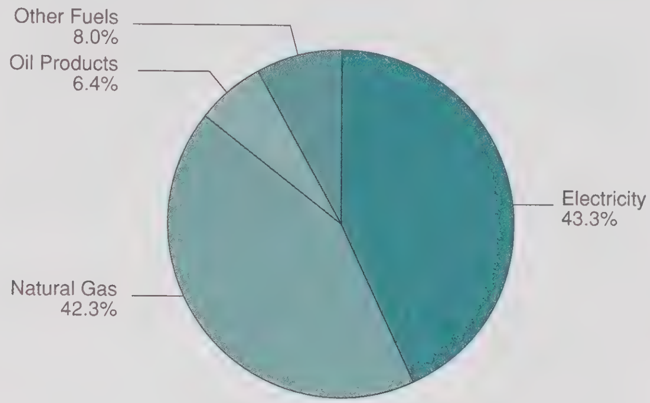
Figure 4.2
Distribution of Commercial Energy Use by Building Type in 1994 (per cent)



936 petajoules

Figure 4.3 presents the distribution of commercial sector energy use by fuel. In 1994, natural gas and electricity were the major energy sources in the commercial sector, accounting together for more than 85 per cent of total energy use.

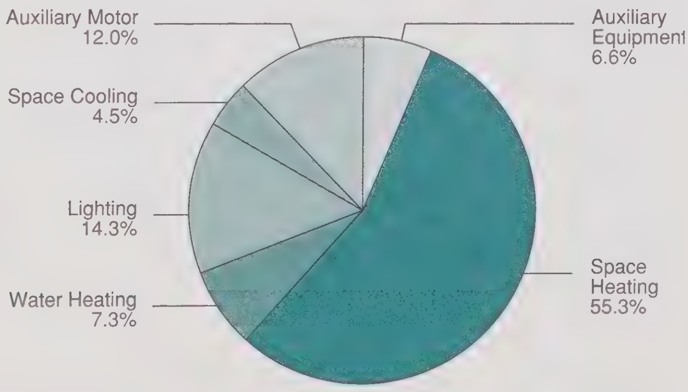
Figure 4.3
Distribution of Commercial Energy Use by Fuel in 1994 (per cent)



936 petajoules

Figure 4.4 presents the distribution of commercial sector energy use by end use. Space heating is by far the single largest commercial sector energy end use, accounting for more than half of total energy use. Lighting is the second largest end use, 14 per cent, followed closely by motive power for pumps, ventilation and other miscellaneous equipment, 12 per cent. Electric plug load, water heating, and space cooling together account for almost 19 per cent of energy use.

Figure 4.4
Distribution of Commercial Energy Use by End Use in 1994 (per cent)

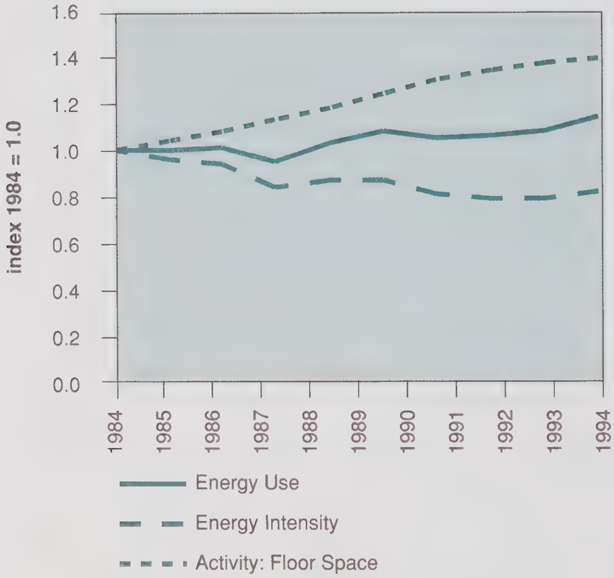


936 petajoules

4.2 Trends in Commercial Energy Use Over the Last Decade

From 1984 to 1994, commercial sector energy use increased by 14 per cent, an average annual rate of 1.3 per cent, reaching 936 petajoules in 1994. Over this period, high growth in commercial sector activity (floor area), totalling about 40 per cent (or an average annual increase of 3.5 per cent), was tempered by a 19 per cent (or 2.1 per cent per year) decline in energy intensity. Figure 4.5 illustrates the evolution of commercial sector energy use, energy intensity and activity from 1984 to 1994.

Figure 4.5
Commercial Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)



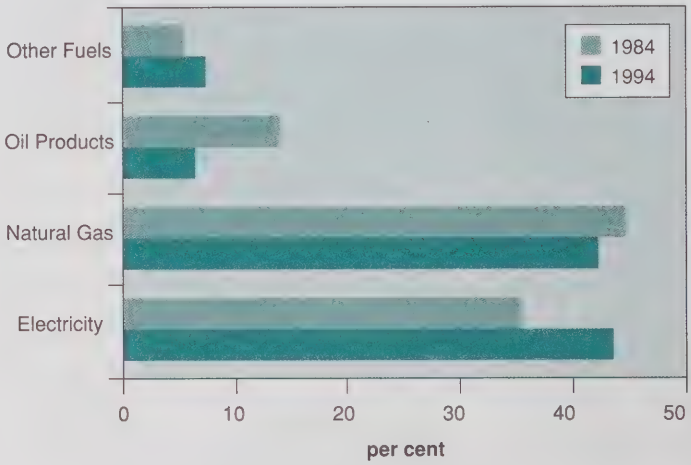
The most marked changes in the distribution of energy use by fuel in the commercial sector over the last decade was the substantial increase in the share of electricity and the concomitant decrease in the share of oil products. These trends are illustrated in Figure 4.6.

The market share for electricity increased by 7 percentage points over the ten-year period beginning in 1984, reaching 43 per cent of commercial energy use (406 petajoules) in 1994.

The market share for oil products decreased dramatically from 14 per cent (118 petajoules) of total commercial energy use in 1984 to 6.4 per cent (60 petajoules) in 1994. This change occurred for a large part in response to the world oil price shocks of the 1970s and 1980s.

The market share for natural gas decreased from some 44 per cent to 42 per cent of commercial energy use between 1984 and 1994. At the same time, natural gas used for space and water heating increased, as it was substituted for oil. Some of the factors underlying these changes were lower natural gas prices and the greater availability of natural gas.

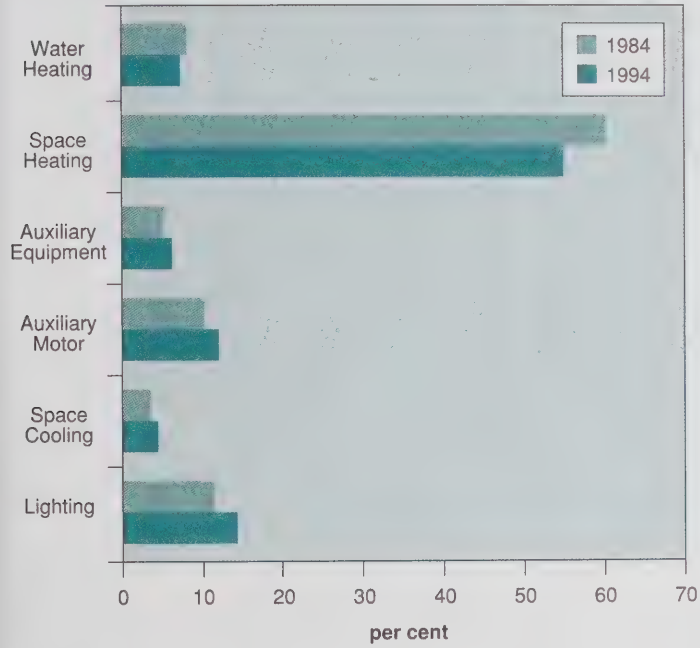
Figure 4.6
Commercial Energy Fuel Shares, 1984 and 1994 (per cent)



As shown in Figure 4.7, energy used for space heating in commercial buildings decreased by almost 6 percentage points, from 61 per cent (497 petajoules) in 1984 to 55 per cent (517 petajoules) in 1994. All electric heating systems slightly increased their share of total energy use during the same period.

The share of energy used for lighting increased to 14 per cent in 1994 from 12 per cent in 1984. Energy used to provide the motive power required in fans, pumps and other equipment also increased by 2 percentage points to 12 per cent in 1994. Finally, energy used to meet space-cooling and auxiliary equipment (fax machines, photocopiers and similar plug load) requirements each increased their share by about 1 percentage point to 5 per cent and 7 per cent respectively, in 1994.

Figure 4.7
Commercial Energy End-use Shares, 1984 and 1994 (per cent)



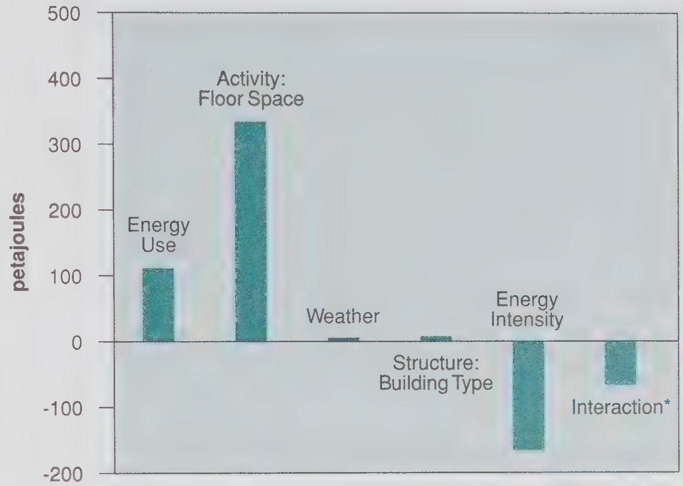
4.2.1 Factors influencing growth in commercial energy use

From 1984 to 1994, commercial sector energy use increased by 114 petajoules (an average annual rate of 1.3 per cent). Figure 4.8 presents the factors influencing commercial energy use over this period.

Strong economic growth in the mid-1980s moved promoters to invest in commercial real estate, leading to average annual increases in commercial floor area of 3.5 per cent per year. The impact of this increase in floor area is reflected in the *activity* bar in Figure 4.8.

Had all other factors except *activity* remained constant at their 1984 levels, commercial sector energy use would have increased by almost 340 petajoules from 1984 to 1994, compared to the observed 114 petajoules.

Figure 4.8
Factors Influencing Growth in Commercial Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

A small part (about 8 petajoules) of the change in total commercial energy use over the 1984 to 1994 period is associated with changes in the distribution of floor area by building type (*structure*). Over this period, the share of floor area accounted for by more energy-intensive building types (offices, retail stores and hotels/restaurants) rose by 3.7 per cent.

Variations in *weather* had minimal impact (less than 1 petajoule) on total commercial energy use between 1984 and 1994. Heating degree days were slightly higher in 1994 compared to 1984, as a result of a colder winter in 1994. This contributed to an increase in space heating requirements. As for cooling degree days, they were slightly lower in 1994 compared to 1984, as a result of a cooler summer in 1994. This led to a decrease in space cooling requirements which offset part of the increased heating load impact.

Despite significant growth in commercial sector energy use from 1984 to 1994, the decline in *energy intensity* over this period contributed to keep energy use 166 petajoules lower than it would otherwise have been in 1994. Some of the factors underlying this decline, including energy efficiency improvements, are discussed below.

4.2.2 Trends in end-use energy efficiency

Changes in the energy intensity of a given building type are influenced by changes in the energy efficiency of the buildings themselves and the equipment they house, including equipment per occupant, as well as by the occupation density of buildings and the behaviour of occupants. Over the past ten years, improvements in the energy efficiency of building energy technologies and improvements in energy management and construction practices have contributed to the reduction in energy intensity of commercial energy use noted above.

Building and equipment energy efficiency

Space heating

Space heating energy requirements are affected by the efficiency of the building itself – i.e, by the characteristics of the building envelope – and by the efficiency of space heating equipment.

The efficiency of boilers and furnaces has increased considerably over the last decade. In the early 1980s, typical oil- and gas-heated buildings were equipped with boilers and furnaces with seasonal efficiencies of about 60 per cent. With improvements, such as the addition of high-efficiency burners, space heating energy efficiency has been increased by up to 10 per cent. Today, new mid- and high-efficiency boilers have a seasonal efficiency of about 80 per cent.

Lighting[1]

Fluorescent lighting accounts for about 70 per cent of the energy used to light office buildings. Energy efficiency of this type of lighting has increased as a result of improvements to conventional fluorescent lighting systems, as well as to increased penetration of more efficient systems.

Standard fluorescent lighting systems are comprised of two fluorescent tubes and one standard core-coil electromagnetic ballast, with a system energy consumption of 96 watts. The energy efficiency of standard fluorescent lighting systems has seen a gradual improvement since 1984, as a result of improved ballasts and lamps.

Better material in electromagnetic ballasts and the recent introduction of electronic ballasts have reduced ballast energy consumption in these systems by 50 to 75 per cent.

Fluorescent lamps have changed radically since they were first introduced during the 1930s. Recent upgrades, such as rare-earth phosphors for tube coating, cathode cut-out and smaller lamp diameters, have improved colour rendition and lighting power and have helped reduce energy consumption.

In 1993, standard fluorescent lamps accounted for 67 per cent of lamp sales, and they continued to dominate the existing market. In applications related to new buildings, however, there is a clear trend towards the installation of more energy-efficient lighting systems (particularly T-8 systems). T-8 systems, which were not commercially available in Canada in 1984, are now estimated to account for 75 to 95 per cent of sales related to retrofit of existing buildings and installation in new buildings.

[1] Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

Space cooling

The energy efficiency of space-cooling systems improved by about 25 per cent over the last decade. Efficiency improvements resulted from technological upgrades such as free-cooling economizers, thermal storage, energy-efficient compressors and fan motors, and larger evaporator and condenser surfaces.

Some of the impact of improvements in space cooling energy efficiency was offset by the rapid market penetration of office and related equipment. This trend led to increased cooling loads because the heat discharge of this equipment increased cooling requirements.

Office equipment[2]

During the late 1970s and early 1980s, personal computers were available only in limited numbers. Today, most office work stations are computerized. This was achieved in part by almost 500% growth in annual sales of microcomputers between 1985 and 1994, with over a million units now sold annually. Since approximately three quarters of microcomputers are sold to business, government and education, most of their added electricity consumption is in the commercial sector.

Even more rapid growth has occurred in other categories of office machinery. For example, sales of facsimile machines grew by a factor of about 10 between 1986 and 1994, and the annual sales of laser printers rose from a tiny base in the mid-1980s to well over a quarter of a million units today. The energy end-use implications of the growth in the density of electrical equipment in commercial buildings has been reinforced by trends toward more powerful processors, larger monitors, and faster printers which have increased average plug loads.

Building occupancy rates

Variations in occupancy rates (occupants per floor area) also affect energy intensity. The higher the occupancy rate of a given building, the higher its energy requirements and energy intensity.

Over the last ten years, the number of occupants per square metre fell by an average of 1.4 per cent per year. This was the result of two offsetting trends: the high rates of investment in commercial structures in the mid-1980s and more recent efforts to rationalize space in buildings. This trend in occupancy rates has had a negative impact on energy intensity.

Behaviour of occupants: the impact of energy management

Occupants' behaviour with respect to energy use also exerts a significant impact on energy intensity and energy use. Over the past decade increased training and information about the rational use of energy in buildings and increased penetration of computerized energy-monitoring systems have contributed to the decline in building energy intensity. Recent U.S. surveys of the commercial sector reveal that heating and cooling energy-management control systems were installed in almost 9 per cent of commercial buildings surveyed in 1992, compared with 3 per cent of buildings in 1983.[3]

[2] Office equipment trends are based on proprietary data provided by Stanley L. Jacobs Inc., Oakville, Ontario.

[3] Energy Information Administration, *Commercial Buildings Characteristics 1992* and *Characteristics of Commercial Buildings 1983*, Washington, D.C.

Energy Efficiency Trends in the Industrial Sector

HIGHLIGHTS

- From 1984 to 1994, industrial sector energy use increased at an average annual rate of 1.5 per cent. As a result, industrial energy use was 391 petajoules higher in 1994 than in 1984. Growth in industrial sector energy use over this period was largely influenced by growth in industrial economic activity.
- From 1984 to 1994, industrial sector activity (measured as gross domestic product) increased at an average annual rate of 1.8 per cent. Had all other factors remained constant over this period and only industrial activity changed, industrial sector energy use would have increased by 490 petajoules.
- Both the sectoral mix of the industrial sector and energy intensity had small impacts on energy use over this same period. These impacts offset part of the influence of activity on energy use.
- First, there was a minor change in the mix of industries within the industrial sector away from energy-intensive industries. Had all other factors remained constant over the period and only the industrial sector mix changed, industrial sector energy use would have decreased by 54 petajoules from 1984 to 1994.
- Secondly, a small decline in energy intensity, brought about in part by better maintenance practices and energy efficiency improvements, also had the impact of offsetting some of the increase in energy use due to growth in activity. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have decreased by 29 petajoules from 1984 to 1994.

The industrial sector is defined as including all manufacturing industries, as well as forestry, construction and mining. In this sector, energy is used in industrial processes as a source of motive power or to produce heat or generate steam. Examples of specific process technologies are electric-arc furnaces, pulp digesters and aluminum smelters.

The analysis presented in this chapter focuses on the largest energy-using industries. Figure 5.1 shows that the six largest energy users – pulp and paper, mining, petroleum refining chemicals, iron and steel, and smelting and refining – account for almost 28 per cent of total activity[1] in the industrial sector[2] (see box titled "MEASURES OF INDUSTRIAL ACTIVITY" on page 27).

5.1 Patterns of Energy Use in Industry

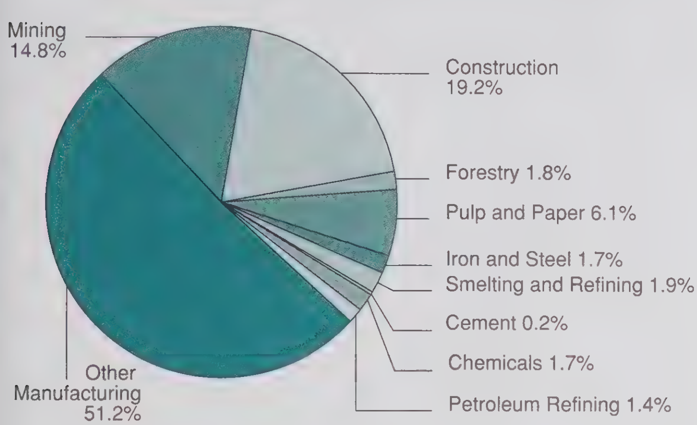
Energy use in the industrial sector amounted to 2841 petajoules in 1994, representing 39 per cent of total secondary energy use. As shown in Figure 5.2, industrial energy use (see box titled "MEASURES OF INDUSTRIAL ENERGY USE" on page 28) is concentrated in a few industries.

[1] The measure of activity used in this chapter is gross domestic product at 1986 prices.

[2] In 1994, industrial sector gross domestic product amounted to $152.7 billion (at 1986 prices) which represents 25.5 per cent of Canada's gross domestic product.

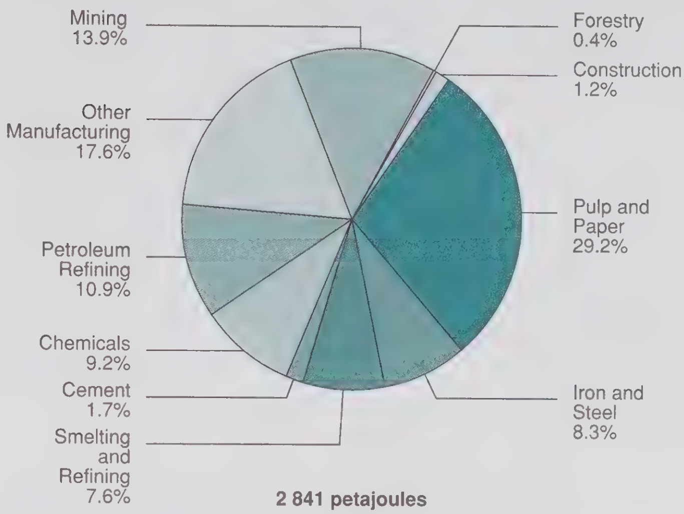
The six largest energy consumers, as noted above, account for almost 28 per cent of the sector's activity and use almost 80 per cent of industrial energy.

Figure 5.1
Distribution of Industrial Activity by Sector in 1994 (per cent)



$152.7 billion ($1986)

Figure 5.2
Distribution of Industrial Energy Use by Sector in 1994 (per cent)



2 841 petajoules

MEASURES OF INDUSTRIAL ACTIVITY

Different measures of industrial activity can be used in the development of energy efficiency indicators. In general, these measures are categorized as measures of economic output and measures of physical output. For the purpose of this report, we have adopted a measure of economic output, i.e., gross domestic product.

The reason for choosing a measure of economic output for the report are the requirements of the factorization method, which is used extensively in the analysis. The factorization method requires that output of all industrial sectors be measured in the same units. A measure of economic output which uses dollars as the common unit meets this requirement.

For other purposes, such as the tracking of sector-specific energy efficiency progress in industry, the use of physical output measures is more suitable. This is the approach chosen by the Canadian Industry Program for Energy Conservation (CIPEC), whose main objective is to promote energy efficiency in the manufacturing and mining sectors and track progress for each participating industrial sector. To do this, CIPEC uses a combination of measures of economic and physical output depending on the sector. Physical output measures are always the first choice, and economic output measures are only adopted in special cases, e.g., where an industry's products are too heterogeneous and numerous to allow the choice of one representative physical output measure for that industry.

We will look into the possibility of modifying the methodology used in this report in the future to allow the use of physical measures of output.

Figure 5.3 shows the distribution of industrial energy use by type of fuel. Almost 45 per cent of oil products consumed in the industrial sector are self-generated fuels used by the petroleum refining industry. In fact, one third of the oil products used by the petroleum refining industry is refinery gas, which provides about 50 per cent of the energy required to separate and alter crude oil.

Wood wastes and pulping liquor account for almost 90 per cent of other fuels. All wood wastes and pulping liquor are consumed as fuel in the pulp and paper industry in boilers and cogeneration systems to generate steam and electricity.

More than 70 per cent of coal, coke, and coke oven gas is used by the iron and steel industry. Coke is used as a reducing agent in producing molten steel in blast furnaces. Coke oven gas is substituted for purchased natural gas at several stages of the process, such as steam generation, reheating of furnaces, and metal heating before finishing.

Figure 5.3
Distribution of Industrial Energy Use by Fuel in 1994 (per cent)

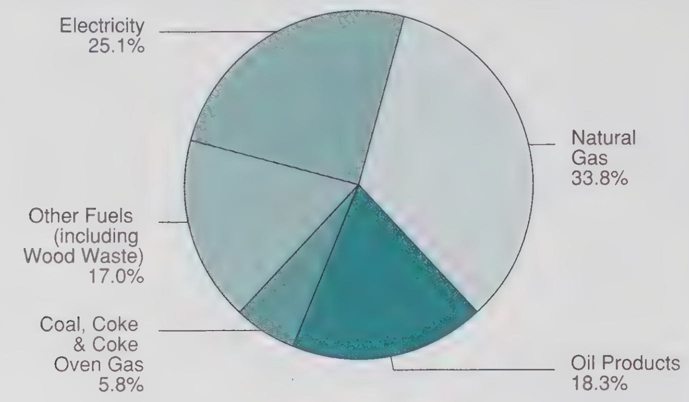
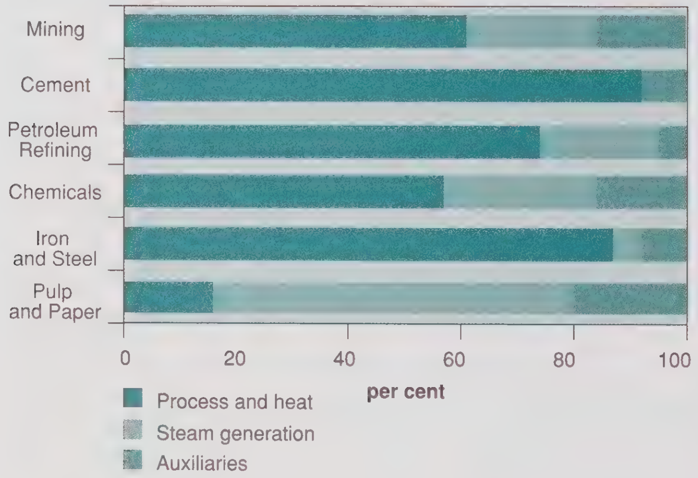


Figure 5.4 shows the distribution of energy use by end use for some of the most energy-intensive industries. Process and heat-generation technologies typically account for more than 50 per cent of any sector's energy use. However, in the pulp and paper industry, more than half of the energy is used in steam generation; steam is required to produce the heat needed for pulp and paper production.

Figure 5.4
Distribution of Industrial Energy Use by End Use for Selected Sectors in 1994 (per cent)



MEASURES OF INDUSTRIAL ENERGY USE

The definition of industrial energy use adopted for this report is a variant of the definition given in Statistics Canada's *Quarterly Report on Energy Supply and Demand* (QRESD). The reason for using this source of data is to ensure consistency in definition among all end-use sectors in Canada. The relationship between the definition of industrial energy use adopted for this report and the Statistics Canada report is documented in Appendix C.

The data presented in this report are slightly different from those used by the Canadian Industry Program for Energy Conservation (CIPEC) to track industry's energy efficiency progress. The database used by CIPEC, which covers the 1990 to 1994 period, is based on a combination of data from the QRESD and from Statistics Canada's *Annual Survey of Manufacturers*. The reason for using the two sources of information rather than using only the QRESD is found in CIPEC's requirement for a higher level of industry detail which does not exist in the QRESD for the reporting years 1990 to 1994.

For the period beginning in 1995, as a result of a joint initiative of CIPEC, NRCan, Environment Canada, Statistics Canada and the Canadian Industrial Energy End-Use Data and Analysis Centre at Simon Fraser University, the *Industrial Consumers of Energy Survey (ICE)*, which underlies the QRESD, was expanded to cover the level of detail required by CIPEC. From that point on, all of the organizations mentioned above will strive to use the same source of industrial energy-use data. The expansion of the ICE survey is a project funded through NRCan's National Energy Use Database Initiative (see side bar "THE PYRAMID VERSUS DATA NEEDS" in Chapter 1).

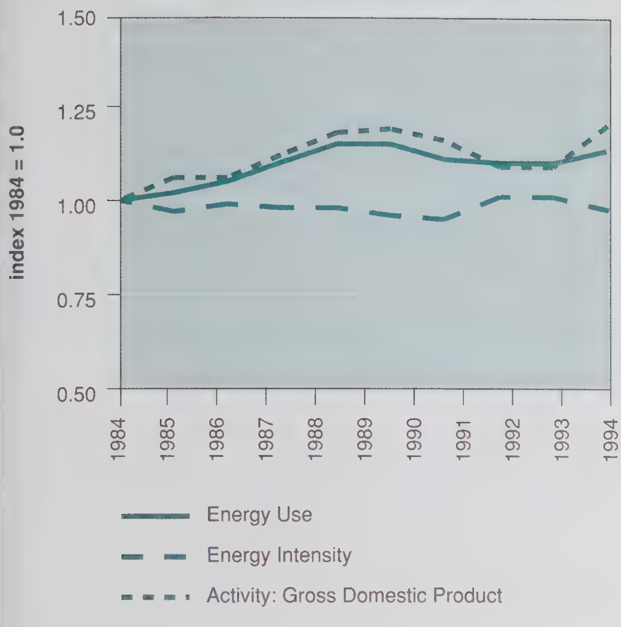
Readers should note that the results of the factorization analysis presented in this report for industry for the period 1990 to 1994 would only be slightly different if data from the CIPEC database were used in place of QRESD data alone.

5.2 Trends in Industrial Energy Use Over the Last Decade

Figure 5.5 shows that since 1984 industrial energy use increased by 16 per cent (average annual growth of 1.5 per cent), despite a 3.3 per cent decline in energy intensity. In short, the impact on energy use of the 20 per cent increase in industrial activity after the 1982 recession more than offset the decline in intensity.

The trends in energy use, activity and intensity from 1984 to 1994 hide much steeper changes in each of these variables in the late 1980s.

Figure 5.5
Industrial Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)



From 1984 to 1990, energy intensity declined by 4.5 per cent, a bigger change than what was observed for the period through 1994. This decline in energy intensity coincides with a period of relatively strong growth in activity for the sector. From 1984 to 1990, industrial gross domestic product increased by 16 per cent (the increase was 19 per cent through the year 1989). These two trends reflect the increase in capacity utilization rates that are typical of periods of economic recovery. As utilization rates increase, activity rises at a faster pace than energy use, thereby leading to declining energy intensity.

Much of the energy intensity decline that occurred since the 1982 recession was offset by an overall increase in energy intensity of about 1.3 per cent from 1990 to 1994, as a result of the sharp slowdown in industrial economic activity over this period.

Figure 5.6 shows the distribution of industrial energy use by fuel in 1984 and 1994. Over this period, industrial sector energy use shifted away from oil products, coal, coke, and coke oven gas towards electricity and natural gas. However, most of the fuel switching in the sector occurred before 1984, when industry reduced its oil consumption and increased its use of electricity and natural gas. Industry's share of oil products decreased from 31 per cent to 22 per cent between 1978 and 1984, reflecting industry's reaction to the 31 per cent increase in fossil fuel prices over that period.

Figure 5.6
Industrial Energy Fuel Shares, 1984 and 1994 (per cent)

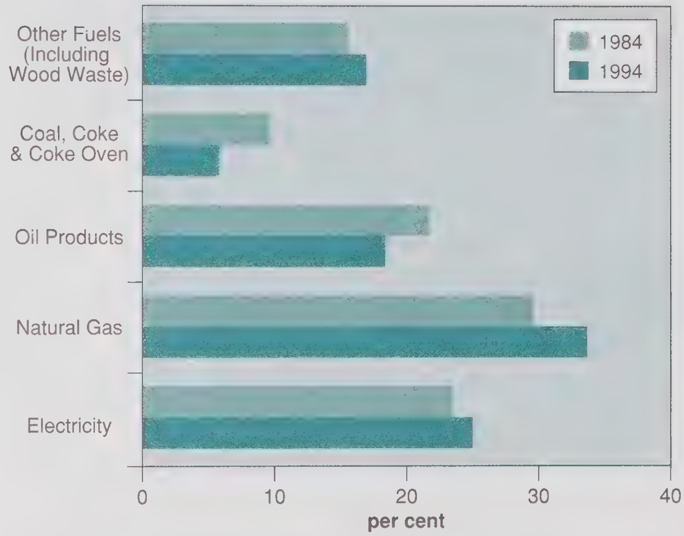
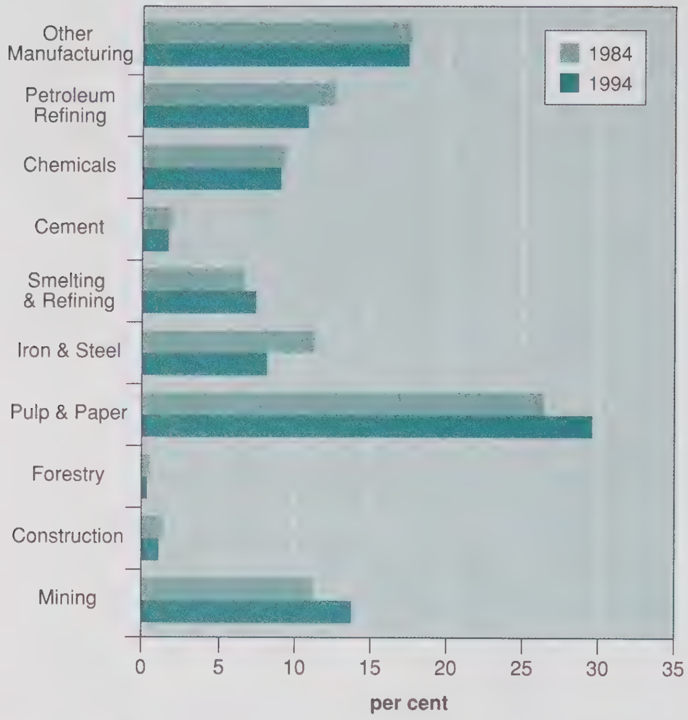


Figure 5.7 presents the change in shares of industrial energy use within the industrial sector between 1984 and 1994. Of the six largest energy-using industries in Canada, the share of energy use of three – mining, pulp and paper, and smelting and refining – increased between 1984 and 1994, while the share of energy use of the remaining three – iron and steel, chemicals, and petroleum refining – declined. The increase in the first three industries slightly outweighed the decrease in the latter three industries, leading to a small increase in the share of energy use accounted for by the six largest energy-using industries, from 78.3 per cent in 1984 to 79.1 per cent in 1994.

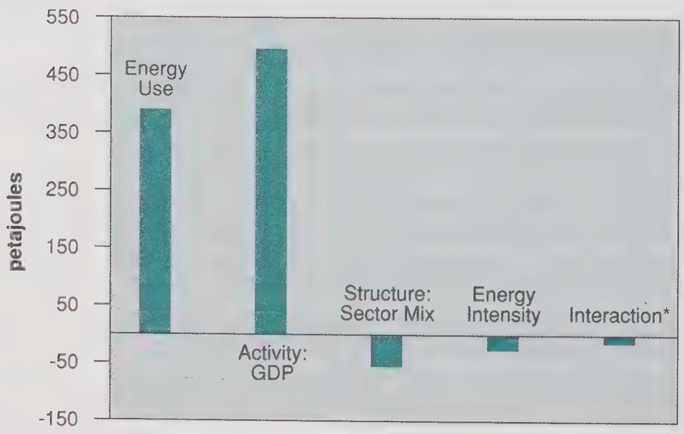
Figure 5.7
Industrial Energy Sector Shares, 1984 and 1994 (per cent)



5.2.1 Factors influencing growth in industrial energy use

From 1984 to 1994, industrial sector energy use increased by a total of 391 petajoules (i.e., an average annual rate of 1.5 per cent). Figure 5.8 presents the factors influencing energy use over this period.

Figure 5.8
Factors Influencing Growth in Industrial Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

Changes in energy use in the industrial sector can be explained by changes in *activity* levels (measured as gross domestic product), changes in *energy intensity* and changes in the mix of industries (*structure*). Figure 5.8 shows that between 1984 and 1994 industrial *activity* was the main contributor to change in industrial energy use. Had all other factors but *activity* remained constant at their 1984 levels, industrial energy use would have increased by 490 petajoules from 1984 to 1994 (or at an average annual rate of 1.8 per cent), rather than the 391 petajoules observed during that period.

From 1984 to 1994, the mix of industries (*structure*) shifted away from energy-intensive industries. The six most energy-intensive industries in Canada – petroleum refining, cement, chemicals, pulp and paper, iron and steel, and smelting and refining – taken together, decreased their contribution to total industrial activity by 2.0 percentage points from 1984 to 1994. Had all other factors except the mix of industries changed from 1984 to 1994, industrial energy use would have been 54 petajoules lower in 1994 than in 1984.

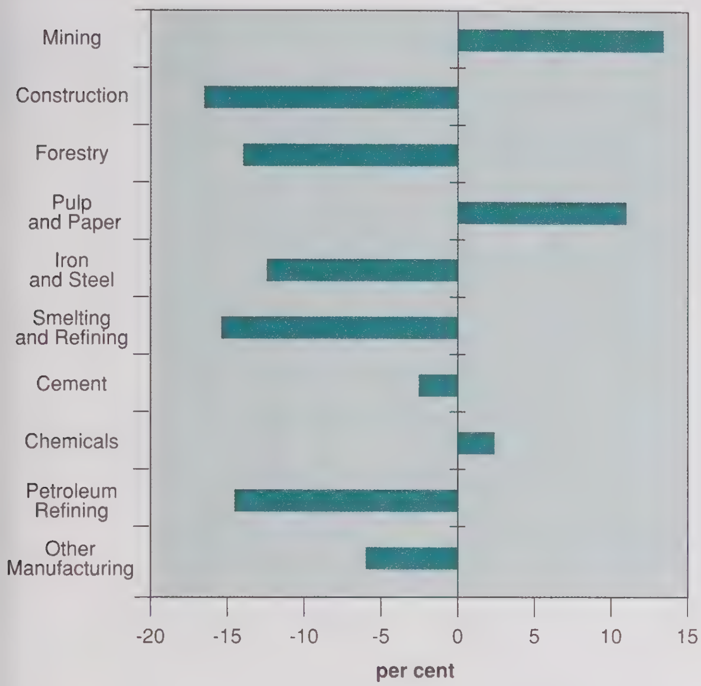
Declines in *energy intensity* also contributed to keeping industrial energy use down. Had only *energy intensity* changed between 1984 and 1994, while activity and structure remained constant, industrial energy use would have been 29 petajoules lower in 1994 than in 1984. The rest of this chapter discusses some of the energy efficiency developments that contributed to the decline in industrial *energy intensity*.

5.2.2 Trends in energy efficiency in selected industries

From 1984 to 1994, energy intensity declined in the iron and steel (14 per cent), petroleum refining (15 per cent), cement (3 per cent) and smelting and refining (15 per cent) industries. Conversely, energy intensity increased in the pulp and paper (11 per cent), chemicals (2 per cent) and mining (14 per cent) industries. These trends

are presented in Figure 5.7. The energy efficiency developments that have contributed to the trends in energy intensity in these industries[3, 4] are discussed below.

Figure 5.9
Changes in Energy Intensity by Industrial Sector, 1984 - 1994 (per cent)



Iron and steel

Because demand for iron and steel decreased in the 1980s, the output of the iron and steel industry fell by 3 per cent between 1984 and 1994. This downturn resulted from a switch to lightweight materials, such as aluminum, plastics and high-strength steel, plus increasing world competition and a 1990 strike that affected major integrated steel producers. Although energy efficiency improvements are difficult to achieve with low production capacities, the iron and steel industry managed to decrease its energy intensity by 14 per cent between 1984 and 1994.

The energy intensity declines in the iron and steel industry resulted both from shifts in the fuel mix and from process improvements. From 1984 to 1994, there was a significant shift from coke and coke oven gas (a decline of 15 percentage points) to natural gas (a percentage point increase of 12.5). Since the energy content of coke and coke oven gas is less than that of natural gas, less energy is required to meet the same energy requirements with natural gas. This resulted in a decline in energy intensity.

The most important technological change in this industry was the shift to the electric-arc furnace technology (EAF), which uses 100 per cent scrap metal and only about 13 per cent of the energy of an integrated mill (about 2 gigajoules of energy per tonne of molten steel, rather than 15 gigajoules per tonne).

In 1984, EAFs were used to produce approximately 26 per cent of steel from scrap, compared with about 33 per cent today. The remaining steel is produced in integrated mills with basic oxygen furnaces that use a mix of pig iron and metal scrap.

The decrease in energy intensity in the iron and steel industry was also a result of replacing ingot casting with continuous casting, which bypasses the semi-finished stage. Use of continuous casting increased from 39 per cent in 1984 to about 82 per cent in 1994. Depending on the product, continuous casting can reduce the energy requirements of the casting process by 50 to 90 per cent.

3 Developments in the chemicals, mining and petroleum refining industries are not discussed in this section for lack of sufficient information. Future reports will attempt to address this situation.

4 Most of the data in this section is taken from the database to the Intra-Sectoral Technology Use Model for Industry (ISTUM-I) which was developed for Canada by the Energy Research Group at Simon Fraser University.

Smelting and refining

The output of the smelting and refining industry has grown by 53 per cent since 1982. Smelting and refining is dominated by aluminum production, which accounted for 72 per cent of the sector's 1994 energy use. Despite growth in production levels, the industry has managed to limit its energy consumption, essentially through energy efficiency improvements.

Aluminum production in Canada has become much more energy efficient as old Soderberg-type smelters are replaced by more efficient smelters. Older smelters use 18 or 19 megawatt hours of electricity per tonne of aluminum while newer smelters use as little as 14 megawatt hours per tonne. In the early 1980s, only 5 per cent of Canadian aluminum production capacity was based on smelters using less than 18 megawatt hours per tonne of aluminum, but by 1994 these types of smelters accounted for 69 per cent of total production capacity.

Cement

The cement industry reduced its energy intensity by almost 3 per cent between 1984 and 1994. Some of this change can be attributed to energy efficiency improvements in this sector.

The most significant change in this industry between 1984 and 1994 was the increased penetration of dry process cement production, which consumes only 3.6 to 4.5 gigajoules of energy per tonne of clinker; the wet process uses between 5.0 and 6.0 gigajoules per tonne. The dry process was used to produce approximately 70 per cent of cement in 1984, compared with close to 85 per cent in 1994.

The dry process uses slightly more electricity than the wet process to better homogenize raw material to reduce grinding requirements and to drive the drying fans. However, the dry process uses considerably less fossil fuel for pyroprocessing (the burning of the raw material) because less evaporation is required. Nearly 40 per cent of energy used for the wet process is accounted for by evaporation.

Pulp and paper

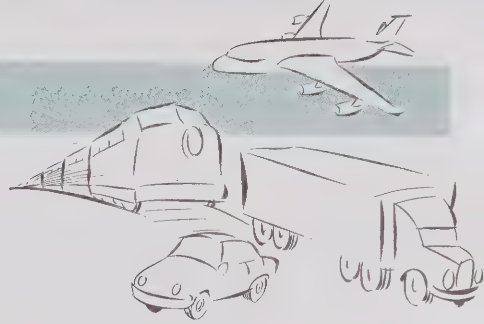
Energy use in the pulp and paper industry increased faster than production between 1984 and 1994, as the industry shifted from fossil fuels to wood wastes and pulping liquor.

Over the last decade, the share of oil products declined by 3.4 percentage points, while the share of wood wastes and pulping liquor increased by 2.4 percentage points. The energy content of wood wastes and pulping liquor is less than that of fossil fuels. As a result, meeting the same end-use requirements using wood wastes and pulping liquor rather than oil products results in an increase in energy use. The impact of this change in fuel mix offset some of the energy efficiency improvements in the pulp and paper industry process.

One of the most significant energy efficiency improvements in the pulp and paper industry was a shift from chemical pulping to mechanical pulping and recycling. Chemical pulping was used for 55 per cent of pulp production in 1985 but for only about 43 per cent of pulp production in 1994. Overall, chemical pulping uses about 20 per cent more energy than mechanical pulping (accounting for fuels generated by these processes, such as pulping liquor and steam).

Producing pulp from recycled paper requires only about 17 per cent of the energy required by chemical pulping and 23 per cent of the energy used in mechanical pulping. However, only about 3 per cent of pulp is currently produced from recycled paper in Canada.

Chapter 6



Energy Efficiency Trends in the Transportation Sector

HIGHLIGHTS

- In the transport sector, the passenger and freight segments exhibited very different trends over the period from 1984 to 1994.
- Growth in activity had the most significant impact on energy use in both sectors. In the passenger transportation sector, growth in activity overwhelmed the effect of structure and energy intensity on energy use. Had only activity levels changed from 1984 to 1994 and all other factors remained at their 1984 levels, growth in passenger transport energy use would have been 2.5 times greater in 1994 than it actually was.
- In the freight transport sector, growth in activity also exerted upward pressure on energy use. However, this effect was less significant than in passenger transport. Had only freight sector activity varied from 1984 to 1994 while structure and energy intensity remained at their 1984 levels, freight energy use would have risen by 79 petajoules rather than 102 petajoules.
- The effect of changing structure was minimal in passenger transport. In freight transport, this effect was quite significant. The shift from rail transport to road transport caused a 48 petajoule increase in freight transport energy use.
- The impact of energy intensity on energy use was similar in the two segments of the transportation sector. As was the case for all of the other sectors analysed in the report, passenger transport energy intensity contributed to keeping the energy use of this sector lower than it otherwise would have been by 178 petajoules. In the freight transport sector the impact of energy intensity was in the same direction but of a different magnitude. Had energy intensity of freight transport not declined, freight transport energy use would have been 40 petajoules higher in 1994 .

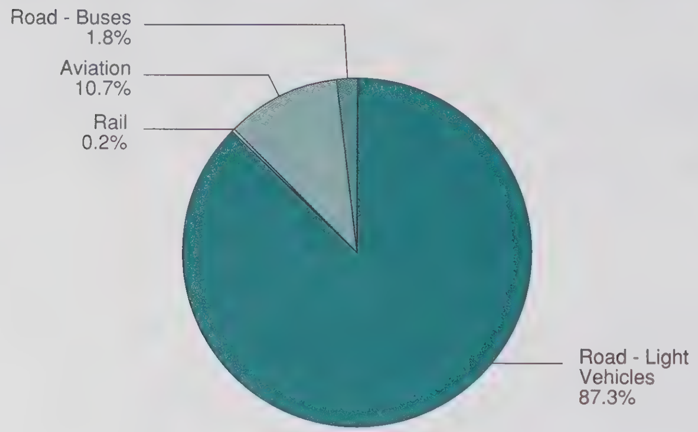
Energy is used in the transportation sector to move people – passenger transportation – and goods – freight transportation. This sector is divided into four mode segments: road, rail, air, and marine.

Two measures of activity are presented for the transportation sector: Passenger-kilometres measures passenger-transport sector activity; tonne-kilometres measures freight-transport sector activity. Figures 6.1 and 6.2 present the distribution of activity by mode in the two classes of the transportation sector.

Figure 6.1 shows that, in 1994, the road (light vehicles and buses) sector accounted for an overwhelming share of passenger transportation activity[1] at 89 per cent. Aviation accounted for the second largest share of passenger-kilometres at almost 11 per cent and rail accounted for only 0.2 per cent. The marine sector is not analysed for passenger transport, as there are no energy data for passenger marine transport.

[1] Passenger transportation activity (passenger-kilometres) does not include the non-airline segment.

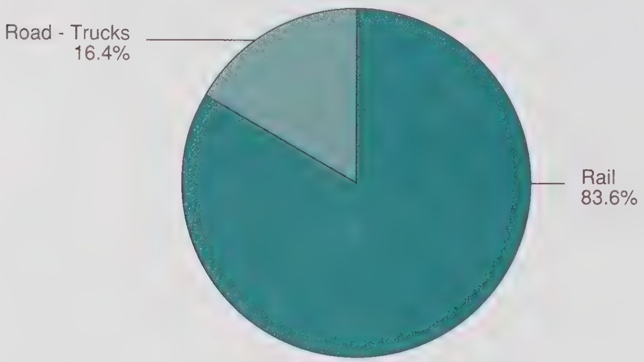
Figure 6.1
Distribution of Passenger-Kilometres by Mode in 1994 (per cent)



passenger-kilometres: 614.3 (billion)

In the case of freight transport, the rail sector accounts for 84 per cent of tonne-kilometres. The road segment[2] accounts for the balance of the sector's activity, 16 per cent. These data are presented in Figure 6.2.[3]

Figure 6.2
Distribution of Tonne-Kilometres by Mode in 1994 (per cent)



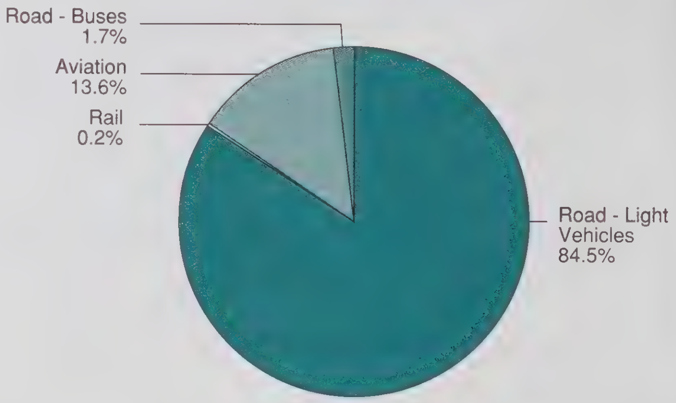
tonne-kilometres: 345.1 (billion)

6.1 Passenger Transportation

6.1.1 Patterns of energy use in passenger transportation

Figure 6.3 illustrates the distribution of passenger transportation energy use by mode. Similar to the distribution of passenger-kilometres, the road segment (light vehicles and buses combined) represents about 86 per cent of total passenger energy use. Aviation and rail account for approximately 14 per cent and 0.2 per cent of total passenger energy use respectively.

Figure 6.3
Distribution of Passenger Transportation Energy Use by Mode in 1994 (per cent)



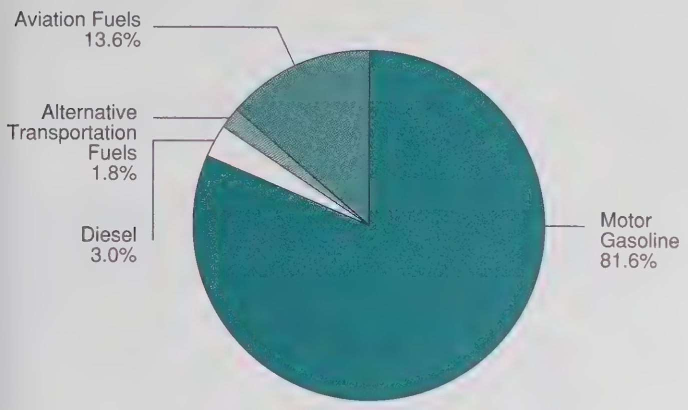
1 269 petajoules

Figure 6.4 illustrates the distribution of passenger transportation energy use by fuel. Motor gasoline accounts for the largest portion, almost 82 per cent of passenger transportation energy use; in comparison, aviation fuels represent almost 14 per cent, and diesel fuel oil represents 3 per cent. The share of alternative transportation fuels was almost 2 per cent.

[2] Road sector freight transport tonne-kilometres only include Canadian inter-city activity by Canadian-domiciled for-hire trucking companies with annual inter-city freight revenues of $1.0 million or more. The revenue threshold changed from the 1989 to the 1990 reporting year, and the tonne-kilometres data were adjusted to reflect this change.

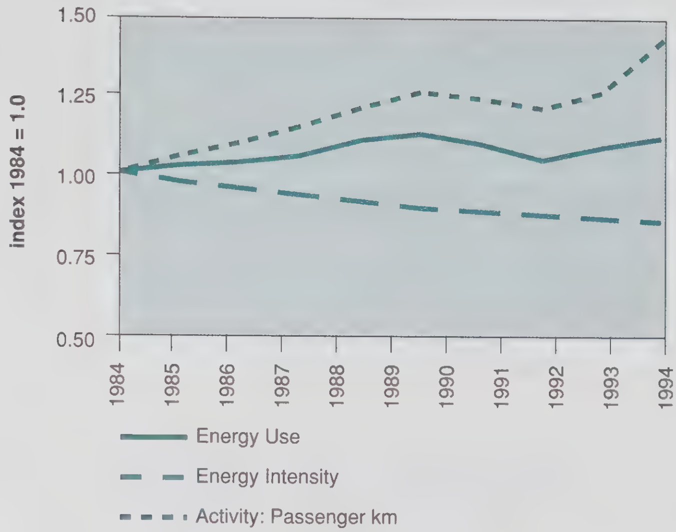
[3] Note that marine freight transport is not included in the distribution of freight transport activity as marine activity is only reported on a tonnage basis. In this regard, tonne-kilometres data were not available.

Figure 6.4
Distribution of Passenger Transportation Energy Use by Fuel in 1994 (per cent)



1 269 petajoules

Figure 6.5
Passenger Transportation Energy Use, Intensity and Activity, 1984 - 1994 (Index 1984 = 1.0)



6.1.2 Trends in passenger transportation energy use over the last decade

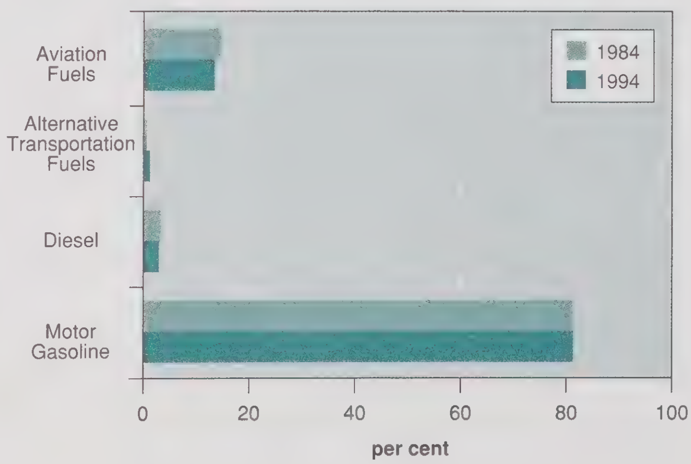
From 1984 to 1994, passenger transportation energy use increased at an average annual rate of 1.5 per cent for a total increase of some 16 per cent over the whole period. This increase came in two distinct steps.

Passenger transportation energy use grew at an average rate of almost 2.3 per cent per year following the recession in the early 1980s to 1233 petajoules in 1989. Then, as a result of economic downturn in 1991, energy use plummeted to a low of 1147 petajoules, thereafter rebounding to grow at an average annual rate of 3.4 per cent through 1994.

Over the decade, the impact on energy use of growth in activity (i.e., passenger kilometres), 3.4 per cent per year on average, was moderated by an average annual decline in *energy intensity* of 1.9 per cent per year. Figure 6.5 depicts the evolution of passenger transportation energy use, intensity and activity from 1984 to 1994.

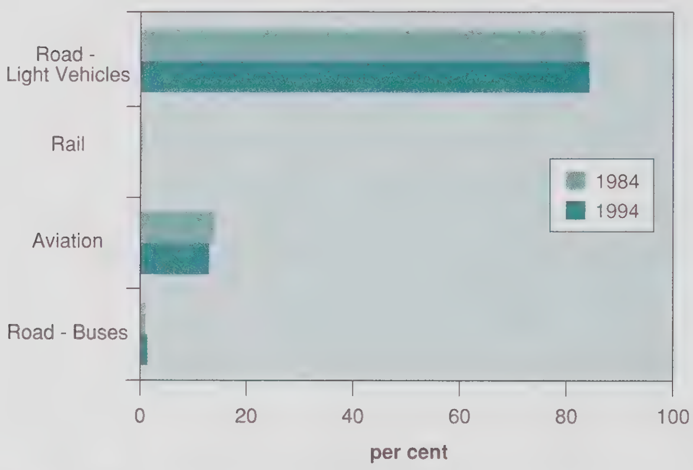
Figure 6.6 illustrates the trend in passenger transportation fuel shares from 1984 to 1994. Fuel shares in 1994 were almost identical to those observed in 1984, except for a slight increase in the shares of alternative transportation fuels from 0.9 per cent to 1.8 per cent and a minor decrease in the shares of aviation fuels and diesel fuel (both down by 0.5 percentage point). The increase in alternative transportation fuels was mostly due to an increase in the use of propane in light vehicles.

Figure 6.6
Passenger Transportation Energy Fuel Shares, 1984 and 1994 (per cent)



The distribution of passenger transportation energy use by mode was as stable as the distribution by fuel. Figure 6.7 indicates that between 1984 and 1994, the share of energy use in the road segment relative to total passenger energy use increased by almost 1 percentage point. The share of energy use accounted for by the aviation segment declined by about one half percentage point, as did the share of rail energy use.

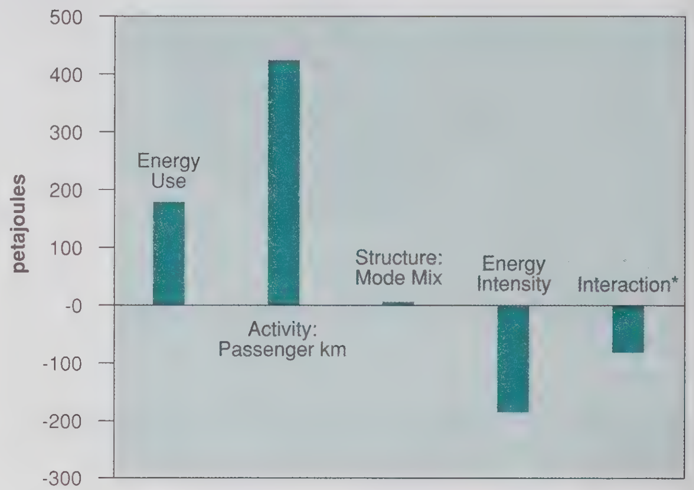
Figure 6.7
Passenger Transportation Energy Mode Shares, 1984 and 1994 (per cent)



6.1.3 Factors influencing growth in passenger transportation energy use

Figure 6.8 illustrates the source of growth in passenger transportation energy use from 1984 to 1994. During this period, activity (measured as passenger-kilometres) increased at an average annual rate of 3.4 per cent. Had all other factors except activity remained constant at their 1984 levels, passenger transportation energy use would have increased by 424 petajoules, rather than the observed 171 petajoules.[4, 5]

Figure 6.8
Factors Influencing Growth in Passenger Transportation Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

The effect of *structural shifts* in passenger transportation (i.e., intermodal substitution, the choice of one mode over another) caused a minor increase in passenger transport energy use from 1984 to 1994. This was due to the shift in the structure of passenger transport (i.e., passenger kilometres) by mode away from bus and rail transport and towards the light vehicles segment. Light vehicles are more energy intensive than bus and rail.

4 Note that two components of the transportation sector were not included in the factorization analysis. These two segments were excluded for lack of suitable activity measures to use in the factorization methodology.

In the passenger transportation sector, non-airline (i.e., commercial/institutional and public administration) air transport was excluded. This segment, which represented 28 petajoules in 1994, declined by 4 petajoules from 1984 to 1994. This change in passenger transport energy use is not explained in the factorization of energy use in this sector.

Similarly, in the freight transport sector, marine transportation was excluded. This segment, which represented 106 petajoules in 1994, grew by 20 petajoules from 1984 to 1994.

5 The change in energy use presented in Figure 6.8 is the actual change for this sector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis excludes the non-airline segment and uses a motor gasoline equivalency value for all fuels.

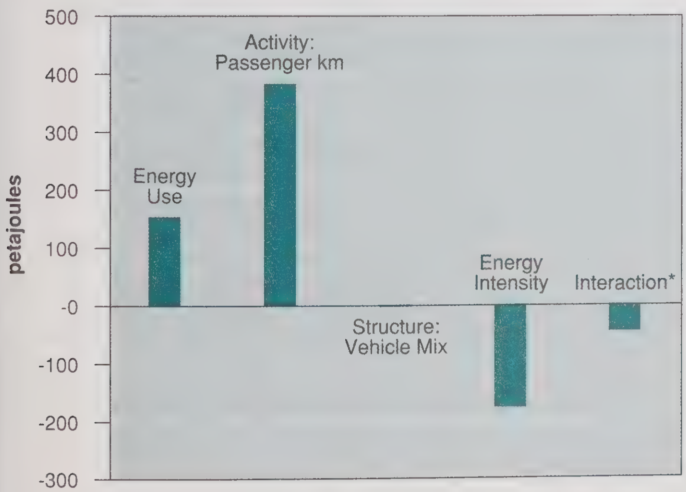
However, the decrease in *energy intensity* (energy use per passenger-kilometre) contributed to offset the increase in energy use associated with demand for passenger travel. Had *energy intensity* not declined, passenger transportation energy use would have been 178 petajoules higher in 1994 than it actually was.

The rest of this section reviews trends in energy use and energy efficiency in the three segments of passenger transportation: road, aviation, and rail. The discussion of the road segment deals with light vehicles (cars and light trucks) and buses separately. More attention is devoted to the light vehicles segment of road transport because of its importance in the total energy use of this sector (84.5 per cent of passenger transportation energy use).

Road – Light Vehicles

Figure 6.9 illustrates the impact of factors which influenced growth in the energy use of the light vehicles segment of road passenger travel from 1984 to 1994. The energy use of this sector increased by 154 petajoules during this period (an average annual increase of 1.6 per cent).[6]

Figure 6.9
Factors Influencing Growth in Light Vehicles Passenger Transportation Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

From 1984 to 1994, *activity* in the light vehicles segment increased at an average rate of 3.6 per cent per year. Had only *activity* changed over this period and other factors remained constant at their 1984 levels, energy use would have increased by 390 petajoules, which is more than two and one half times the actual increase.

The increase in *activity* was the result of a number of factors, including growth in the number of households and income (see Figure 6.10).

As household income grew over the 1980s, so did the number of cars per household, even though the number of persons per household declined. Average distance travelled by cars and light trucks grew at a rate of almost 1.7 per cent per year during this period.

Figure 6.10
Economic Indicators, 1984 - 1994 (index 1984 = 1.0)

As for *structural shifts*, the trend that began in the 1970s toward small cars and light trucks continued in the 1980s (see Figure 6.11). This shift towards less energy-intensive vehicles contributed to mitigating the increase in the light vehicles segment of road-sector energy use by 5 petajoules.

6 The change in energy use presented in Figure 6.9 is slightly different from the actual change in light vehicles passenger transport energy use because the factorization of energy use for this sector uses a motor gasoline equivalency value for all fuels.

Figure 6.11
Distribution of the Stock of Passenger Vehicles by Class, 1984 - 1994 (per cent)

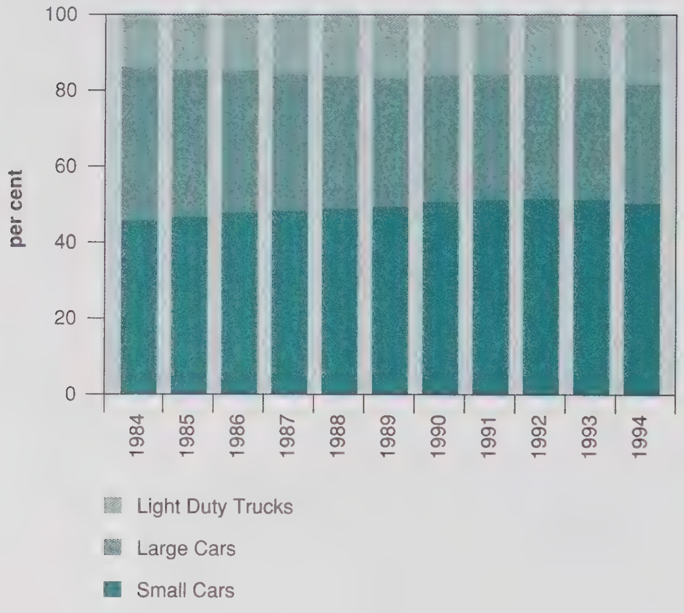


Figure 6.12
Road Transportation Price Indicators, 1984 - 1994 (Index 1984 = 1.0)

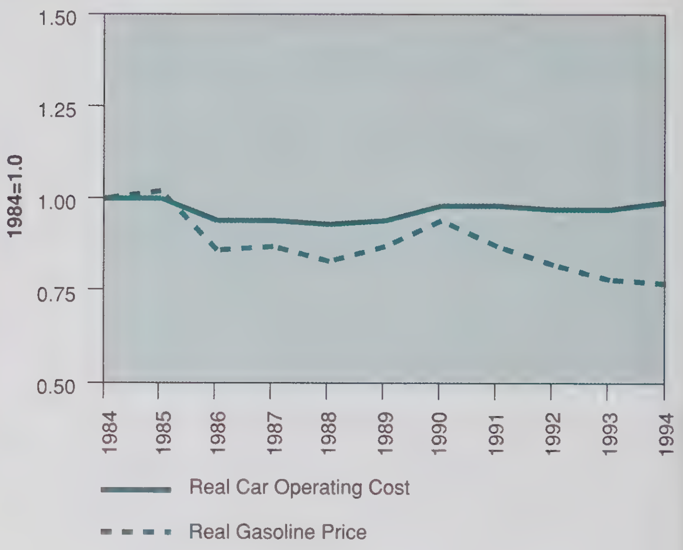
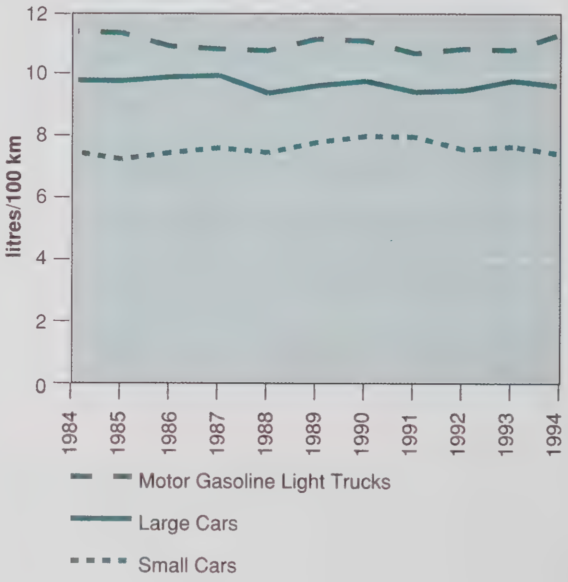


Figure 6.13
Trends in New Vehicle Fuel Economy, 1984 - 1994 (litres per 100 km)



The most important factor mitigating the increase in the light vehicles segment of road passenger transport energy use was the decline in *energy intensity*. Had *energy intensity* not changed from its 1984 level, energy use in the light vehicles segment would have increased by 325 petajoules (i.e., more than twice the actual increase in light vehicles passenger transport energy use of 154 petajoules).

The *energy intensity* decline was no doubt due to the penetration of more efficient vehicles into the vehicle stock. In the 1970s and early 1980s, as the real price of gasoline increased, many fuel-efficiency improvements were made to new cars and light trucks (see Figure 6.12). However, gasoline prices and operating costs have declined since 1984, and the average fuel consumption per 100 kilometres of new vehicles has remained relatively flat since then (shown in Figure 6.13).

Between 1970 and 1984, the fuel efficiency of new small cars improved on average by 2.2 per cent per year, while large cars and light trucks improved by 3.7 per cent per year. Since 1984, the average fuel efficiency of new vehicles has hardly changed, fluctuating around 1984 levels.

Technological fuel-efficiency improvements usually include improvements to the body and drive-train, as well as engine upgrades. Improvements to the body and drive-train include transmission changes (e.g., increased number of gears, electronic overdrive), reduced weight, reduced drag (reduced wind resistance), as well as better performing tires that reduce tire resistance to road pavement, (e.g., low-profile performance tire, synthetic rubber composition), lubricants (e.g., synthetic lubricant that reduces drive-train friction) and accessories (e.g., electric cooling fans to replace belt-driven fans). Engine upgrades can improve fuel efficiency and performance through electronic controls, reduced internal friction, and better valve controls.

The typical 1970 passenger vehicle weighed 4000 pounds and had rear-wheel drive, poor aerodynamics, a V8 carburetor engine and a three-speed automatic transmission. However, vehicle characteristics gradually changed (see Table 6.1). In 1984, passenger vehicles typically weighed about 3000 pounds, and half of these vehicles had front-wheel drive and improved aerodynamics. Four- and six-cylinder engines with throttle-body fuel injection and overdrive transmission were also more common. These changes led to a 36 per cent improvement in fuel efficiency between 1970 and 1984.

Today, new cars commonly have four- or six-cylinder engines and multi-point fuel injection. They often use multi-valve technology; they weigh about 3200 pounds; and they have improved aerodynamics. More than 80 per cent have front-wheel drive, and 90 per cent of new cars with automatic transmissions have four-speed overdrive. Trends towards heavier and more powerful vehicles between 1984 and 1994 worked towards offsetting technological improvements, resulting in only about a 2 per cent increase in fuel efficiency over this period.

Road – Bus

From 1984 to 1994, *activity* levels (passenger kilometres) of inter-city bus passenger transportation fell, while intra-city bus transportation *activity* increased. The net effect of these two changes was an average annual increase of 1 per cent in bus passenger transportation energy use.

Table 6.1
Typical New Car Characteristics for 1970, 1984 and 1994

FEATURE	1970	1984	1994
Transmission	Automatic	Automatic	Automatic
Number of gears	3	3-4	4
Control	Mechanical	Mechanical	Electronic
Overdrive	None	Some non-electronic; mainly manual transmission	Electronic
Drive	Rear wheel	More than 50% front wheel	Front wheel
Weight	More than 4 000 lbs.	About 3 000 lbs.	About 3 200 lbs.
Drag	More than 40	Below 40	Below 30
Tires	Belted	Radial	Radial
Engine	6–8 cylinders	4–6 cylinders	4–6 cylinders
Fuel control	Carburetor	40% fuel injection; mostly throttle body	Multi-point fuel injection
Valves per cylinder	2 valves	2 valves	2–4 valves
Horsepower	Approx. 135	Approx. 100	Approx. 140
Lab-tested Fuel economy	13.3 L/100 km	8.4 L/100 km	8.3 L/100 km

Aviation

From 1984 to 1994, air passenger transportation *energy intensity* declined at an average annual rate of 2.3 per cent per year, while *activity* in this sector increased significantly with an average annual growth rate of 4.1 per cent. The net effect of these two offsetting trends was an average annual increase in passenger air transport energy use of 1.1 per cent.

Significant fuel savings were achieved in passenger air transport through fleet renewal (e.g., newer aircrafts characterized by more efficient engines and design). However, there were no significant gains achieved in the ratio of passenger-seating utilization to capacity.

Rail

Passenger rail transportation energy use decreased by close to 9 per cent per year on average since 1984. Over this period, the average number of passenger coaches per train declined from 6.1 in 1984 to 5.3 in 1994. The reduction in passenger train infrastructure in the late 1980s left little room for fleet efficiency improvements through material renewal.

6.2 Freight Transportation

The *activity* data underlying the analysis presented in this section are incomplete. As a result, the coverage of energy use is broader than that of tonne-kilometres. The reader should use the freight transportation sector analysis with care.

6.2.1 Patterns of energy use in freight transportation

Figure 6.14 illustrates the distribution of freight transportation energy use by mode. The road segment represents about 72 per cent of total freight transport energy use; marine accounts for approximately 16 per cent of total freight transport energy use. Energy used in the rail segment represents about 13 per cent of freight transport energy use.

Figure 6.14
Distribution of Freight Transportation Energy Use by Mode in 1994 (per cent)

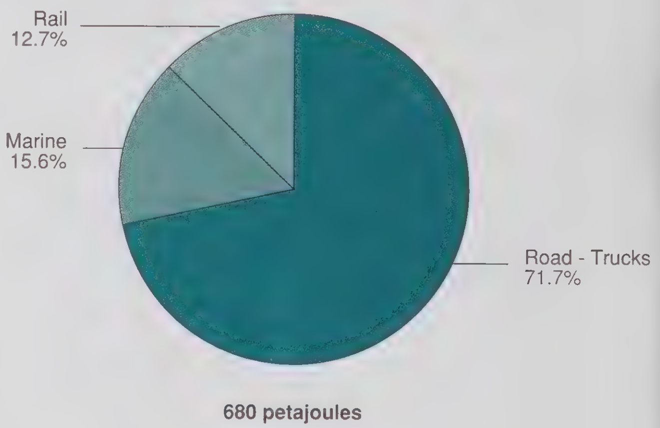
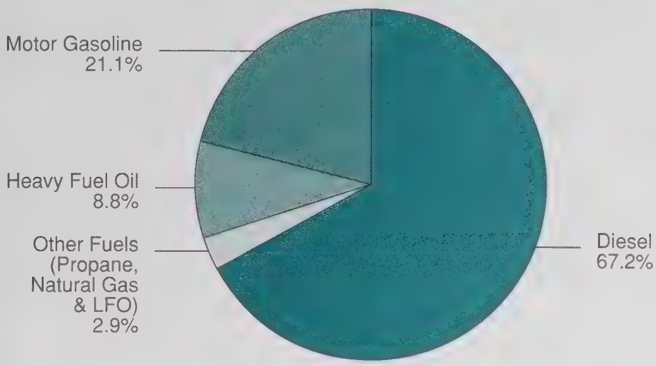


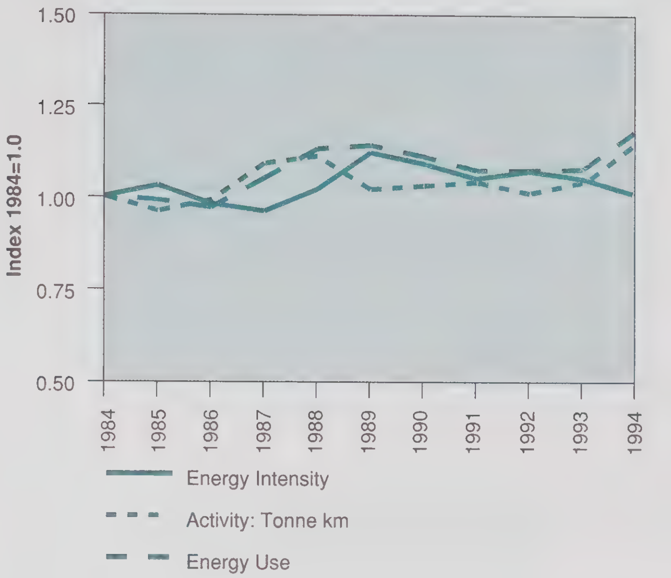
Figure 6.15 illustrates the distribution of freight transportation energy use by fuel. Diesel accounted for the largest portion, 67 per cent, of freight transportation energy use; motor gasoline represented 21 per cent; and heavy fuel oil 9 per cent. The share of propane, natural gas and light fuel oil together was about 3 per cent.

Figure 6.15
Distribution of Freight Transportation Energy Use by Fuel in 1994 (per cent)



680 petajoules

Figure 6.16
Freight Transportation Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)



6.2.2 Trends in freight transportation energy use over the last decade

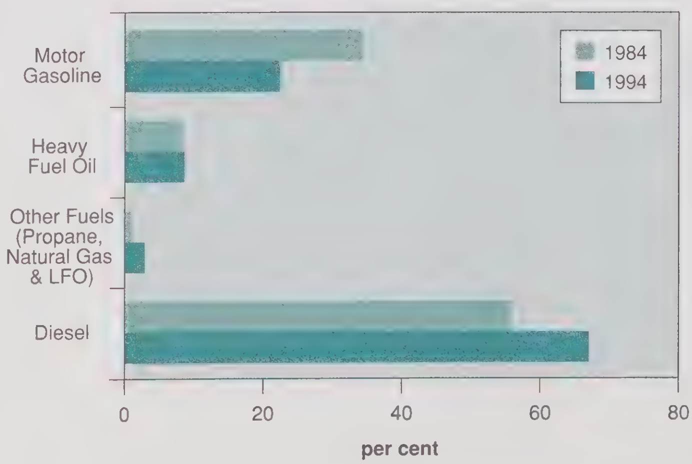
From 1984 to 1994, freight transportation energy use increased at an average annual rate of 1.6 per cent for a total increase of almost 18 per cent over the whole period.

From 1984 to 1989, freight transportation energy use grew at an average rate of almost 2.6 per cent per year, only to decline by about 1.8 per cent per year from 1989 to 1992, a result of the most recent recession. From 1992 to 1994 freight transport energy use grew again very rapidly, 4.4 per cent per year, to reach its highest level of the whole decade, 680 petajoules.

The impact on energy use of growth in *activity* (i.e., tonne-kilometres) of 1.5 per cent per year on average was enhanced by an average annual increases in *energy intensity* of 0.15 per cent per year. Figure 6.16 depicts the evolution of freight transportation energy use, intensity and *activity* from 1984 to 1994.

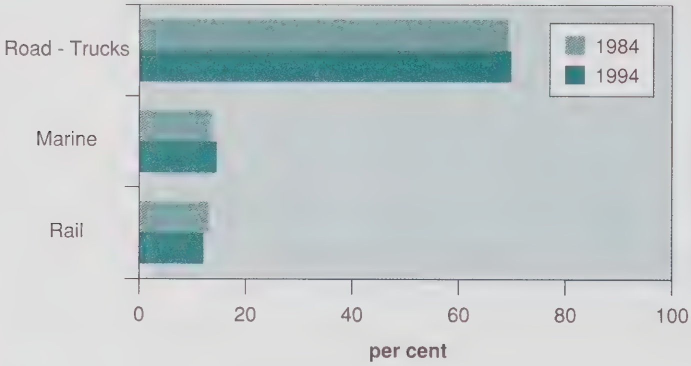
Figure 6.17 illustrates the trend in freight transportation fuel shares from 1984 to 1994. The share of diesel increased significantly over the period. The increased use of diesel was mainly due to an overall growth in the truck fleet and an increased penetration of diesel-fuelled, mid-size and large trucks. Since the increase in the share of diesel was achieved at the expense of motor gasoline, the motor gasoline share declined accordingly from 34 per cent to 21 per cent.

Figure 6.17
Freight Transportation Energy Fuel Shares, 1984 and 1994 (per cent)



The distribution of freight transportation energy use by mode shows little change in 1994 relative to 1984. The road segment continues to account for the bulk of energy use, 72 per cent. There was a slight change in the shares of energy use accounted for by rail and marine freight transportation. Rail energy use declined by 1.1 percentage points to 12.7 per cent, while marine energy use increased 0.8 percentage point to 15.6 per cent. These data are presented in Figure 6.18.

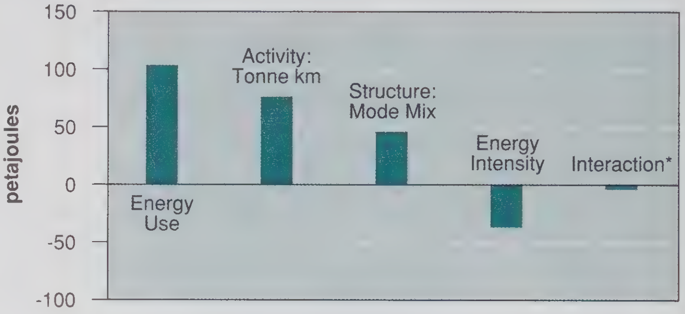
Figure 6.18
Freight Transportation Energy Mode Shares, 1984 and 1994 (per cent)



6.2.3 Factors influencing growth in freight transportation energy use

Figure 6.19 illustrates the source of growth in freight transportation energy use from 1984 to 1994. During this period, activity (measured as tonne-kilometres) increased at an average annual rate of 1.5 per cent. Had all other factors except activity remained constant at their 1984 levels, freight transportation energy use would have increased by 79 petajoules, rather than the observed 102 petajoules.[7, 8]

Figure 6.19
Factors Influencing Growth in Freight Transportation Energy Use, 1984 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

The effect of *structural shifts* in freight transportation caused an increase of 48 petajoules in freight transport energy use from 1984 to 1994. This was due to the shift in modes from rail to road.[9] The *energy intensity* of trucks is significantly larger than that of trains.

As for the *energy intensity* of freight transport (energy use per tonne-kilometre), it was instrumental in keeping total freight transport energy use lower than it would otherwise have been. Had freight *energy intensity* not changed as it did and instead remained at its 1984 level, energy use in this sector would have been 40 petajoules higher.

The apparent contradiction between data on *energy intensity* of freight transportation presented in Figure 6.16 and those presented in Figure 6.19 is due to a different level of disaggregation of the two sets of information.

7 See footnote 3 in this chapter.

8 The change in energy use presented in Figure 6.19 is the actual change for this sector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis excludes the marine segment and uses a motor gasoline equivalency value for all on-road fuels other than diesel.

9 Note that the marine segment could not be analyzed due to a lack of tonne-kilometres data.

Data in Figure 6.16 describe the aggregate intensity of freight transport. The aggregate *energy intensity* is a weighted average of the energy intensities of each freight mode. As such, the aggregate intensity reflects the impact of the mode mix of freight energy use, as well as the impact of the mode-specific energy intensities. Data in Figure 6.19 disaggregate these two components and show that mode-specific energy intensities did in fact decline quite significantly but that this decline was offset by a shift towards the more energy-intensive mode.

Chapter 7

Energy Efficiency Trends from 1990 to 1994

HIGHLIGHTS

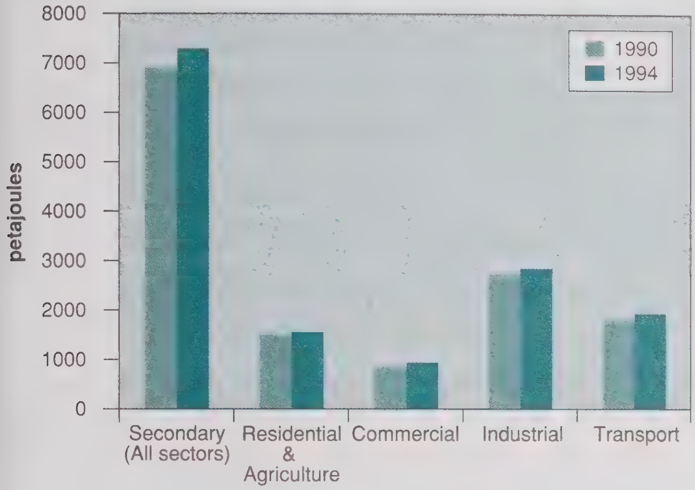
- From 1990 to 1994, secondary energy use increased at an average annual rate of 1.3 per cent. As a result, energy use was 382 petajoules higher in 1994 than in 1990.
- As for the period from 1990, growth in activity levels in all end-use sectors exerted upward pressure on secondary energy use. Had only activity levels increased since 1990 and other factors remained at their 1990 levels, energy use would have increased by 492 petajoules rather than by 382 petajoules.
- Weather and structural shifts also contributed to the increase in energy use. The colder weather of 1994 caused energy use to be 49 petajoules higher than it would otherwise have been.
- In all sectors but freight transport, shifts in the structure of activity favoured more energy-intensive segments of the economy, again contributing to the increase in energy use. The combination of the structural shifts in these sectors offset a shift in the opposite direction that took place in freight transport. Had only structure changed from 1990 to 1994, energy use would have grown by 23 petajoules.
- Energy intensity declined in all sectors but freight transport. The impact of these declines was to keep energy use from increasing more than it actually did. Had energy intensity remained at its 1990 level in all sectors, secondary energy use would have increased by an additional 123 petajoules over the period.
- In the end, while energy efficiency led to declines in energy intensity and, ultimately, the mitigation of increases in energy use and carbon dioxide emissions, other factors have more than offset this impact, and secondary energy use continued to increase. It is important to note, however, that in the absence of energy efficiency improvements and the ensuing energy-intensity declines, secondary energy use would have increased at a significantly faster rate than it actually did from 1990 to 1994.

This chapter reviews energy efficiency trends from 1990 to 1994. The year 1990 was chosen to coincide with the base year of Canada's commitment to work toward stabilizing greenhouse gas emissions in the year 2000. This will allow trends in energy efficiency to be examined against Canada's environmental objectives. Future annual energy efficiency reviews will also use 1990 as the base year.

Figure 7.1 sets out secondary energy use by sector for the years 1990 and 1994. Secondary energy use in Canada increased from 6932 petajoules to 7314 petajoules, an average annual rate of 1.3 per cent over this period. Industrial energy use, which increased by 128 petajoules, continues to account for the largest share of secondary energy, about 39 per cent in 1994. Transportation sector energy use (including the passenger and freight sub-sectors) increased by 110 petajoules over the same period and represents the second largest share of energy use, almost 27 per cent in 1994. Residential

sector energy use grew by 81 petajoules from 1990 to 1994 and accounts for 19 per cent of secondary energy use. Finally, commercial sector energy use saw an increase of 72 petajoules.

Figure 7.1
Secondary Energy Use by Sector, 1990 and 1994 (petajoules)



7.1 Factors Influencing Growth in Secondary Energy Use from 1990 to 1994

Table 7.1[1] presents the results of the sectoral factorization analysis aggregated to the secondary energy level. This analysis attributes an impact on the change in secondary energy use to four driving factors: *activity*, *structure*, *weather* and *energy intensity*. From 1990 to 1994, secondary energy use increased by 382 petajoules.

It is evident from the data in Table 7.1 that growth in secondary energy use was most influenced by growth in *activity* levels in each end-use sector. Had only the level of *activity* changed in each sector from 1990 to 1994, while *structure*, *weather* and *energy intensity* remained at 1990 levels, secondary energy use would have increased by 492 petajoules; a change equivalent to almost 130 per cent of the actual increase in energy use over the period.

Table 7.1
Factors Influencing Growth in Secondary Energy Use, 1990 - 1994 (petajoules)

SECTOR	Energy Use 1990	1994	1994 less 1990 (d)	Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction	Other
Residential	1 311	1 392	81	103.9	0.1	40.0	-59.2	-3.5	n.a.
Commercial	864	936	72	72.0	3.9	9.4	-12.8	-0.3	n.a.
Industrial	2 713	2 841	128	92.9	69.1	n.a.	-20.7	-13.6	n.a.
Transportation	1 839	1 949	110	223.1	-50.6	n.a.	-30.2	-18.8	-12
Passenger (a)	1 195	1 269	75	152.8	1.2	n.a.	-57.7	-10.3	-11
Freight (b)	645	680	35	70.3	-51.8	n.a.	27.5	-8.5	-2
Agriculture (c)	204	195	-10	n.a.	n.a.	n.a.	n.a.	n.a.	-10
TOTAL	6 932	7 314	382	492	23	49	-123	-36	-22

(a) The factorization excludes the non-airline (commercial/institutional and public administration) air sector. The difference in energy use for this component is shown in the "Other" column.

(b) The factorization excludes the marine freight sector. The difference in energy use for this component is shown in the "Other" column.

(c) The factorization analysis was not done for the agriculture sector. The difference in energy use for this component is shown in the "Other" column.

(d) The difference in energy use between 1990 and 1994 and the sum of the activity, structure, weather and energy-intensity effects for passenger and freight transport are slightly different because of i) the exclusion from the factorization analysis of the marine segment in freight transport and the non-airline segment in passenger transport and ii) the fact that the factorization of energy use for these sectors was done using motor gasoline equivalency values (see Chapter 6 footnotes for more detail). The same differences are found at the secondary energy use level in addition to the difference due to the exclusion of agriculture from the factorization.

[1] Table 7.1 presents results for all the sectors to which the factorization method was applied. This method was not applied to the agriculture sector, nor was it applied to the non-airline (i.e., commercial/institutional and public administration) air sector and the marine transport sector. The level and change in energy use for these sectors is included in the "Other" sector category in Table 7.1, and no impacts on energy use are attributed to activity, weather and intensity for this segment.

Structure and *weather* also contributed to the increase in secondary energy use since 1990. Structural change over this period favoured a shift in the distribution of sector *activity* towards more energy-intensive components of the Canadian economy. This shift contributed 23 petajoules to the increase in secondary energy use.

Weather also contributed to the increase in secondary energy use. The winter of 1994 was much colder than the winter of 1990, leading to increased space heating requirements and contributing to increased secondary energy use by 49 petajoules.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1994. Had *energy intensity* remained at its 1990 level and only *activity* levels, *structure* and *weather* changed, secondary energy use would have been 123 petajoules higher in 1994 than it actually was.

At the aggregate secondary level, it is difficult to understand the factors underlying the decline in *energy intensity*. For this reason, the rest of this chapter is devoted to a review of sectoral trends in energy use and *energy intensity*.

Before we begin the sectoral review, however, it is important to point out that the analysis of changes in *energy intensity* cannot be constrained to the period being studied. This is particularly important, given the short time period reviewed in this chapter.

When analyzing trends in *energy intensity* and the energy efficiency improvements that underlie these trends over a given period, one might tend to confine the analysis to the period under review. Such an approach ignores the important impact of past energy efficiency gains on current energy use and intensity.

Although significant energy efficiency gains were realized over the 1990 to 1994 period, these improvements have had a very limited impact on the change in *energy intensity* over this period. On the other hand, the energy efficiency improvements in the 10 to 20 years preceding this period are most important.

Only a fraction of today's capital stock is composed of products that have entered the market since 1990. The majority of the stock is composed of products that have penetrated the market over the last two decades. It will take several years for recent energy efficiency improvements to significantly affect the average efficiency of the stock of appliances and equipment used in Canadian households.

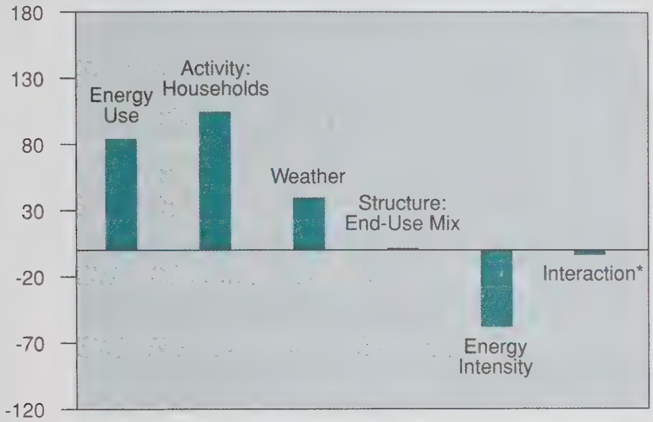
In the case of household appliances, for example, results of *1993 Survey of Household Energy Use* indicate that the average age of the six major appliances used in Canadian households in 1993 ranged from 8.3 years for dishwashers to 11.9 years for freezers, and the average age of hot air natural gas furnaces was 12.5 years. In this regard, the decline in *energy intensity* observed for the period from 1990 to 1994 is a reflection of the average efficiencies of appliances used in Canadian households today, most of which were acquired over the past 15 years.

As sectoral developments are reviewed in the following sections, the reader should keep in mind that the observed energy-intensity changes over the 1990 to 1994 period were moulded by energy efficiency gains that occurred in the 1970s and the 1980s, as well as by more recent improvements.

7.2 Factors Influencing Growth in Residential[2] Energy Use from 1990 to 1994

Figure 7.2 presents the decomposition of residential energy use according to the influence exerted on it by *activity*, *weather*, *structure* changes, and *energy intensity*.

Figure 7.2
Factors Influencing Growth in Residential Energy Use, 1990 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

Residential energy use increased by 81 petajoules from 1990 to 1994. This increase was largely driven by the increase in sector *activity* (measured as the number of households). In fact, had all other factors influencing residential energy use remained at their 1990 levels and only *activity* changed, energy use in this sector would have increased by 104 petajoules.

Weather also contributed to an increase in residential energy use. The unusually cold winter of 1994 contributed to a 40 petajoule increase in energy use.

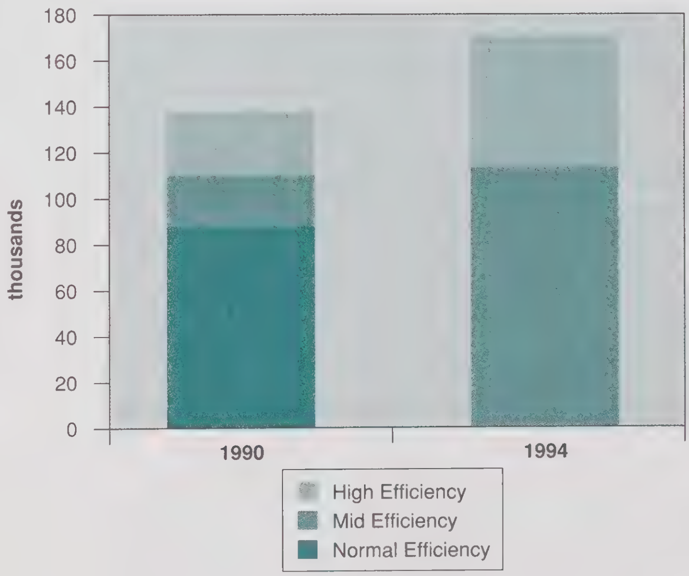
Only *energy intensity* managed to offset the increase in residential energy use. If *energy intensity* had remained at its 1990 level, the amount of energy consumed in the residential sector in 1994 would have been some 59 petajoules higher than it actually was.

Since 1990, significant energy efficiency gains have been achieved for five of the six major household appliances. The energy efficiency of new refrigerators and freezers improved by 31 per cent. During the same period, however, the size of standard refrigerators increased, a trend which slightly offset energy efficiency improvements.

Other notable energy efficiency improvements were achieved for electric clothes dryers (16 per cent), dishwashers (14 per cent), and clothes washers (7 per cent).

The energy efficiency of natural gas space heating also improved significantly. Figure 7.3 shows that in 1990 approximately 63 per cent of shipments of natural gas furnaces were conventional or normal-efficiency units, with annual fuel utilization efficiencies of about 65 per cent. However, since 1992, manufacturers have phased out conventional gas furnaces and now produce only mid- and high-efficiency units, ranging in efficiency from 78 to 96 per cent.

Figure 7.3
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1994 (thousands)

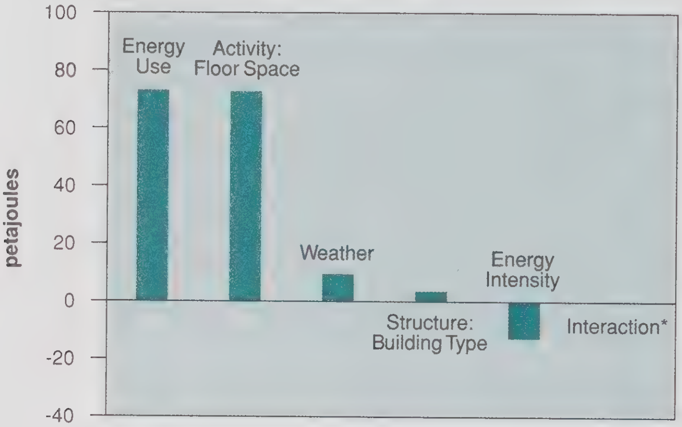


[2] This section addresses only the residential sector, exclusive of agriculture. See footnote 1 in Chapter 2. In 1994, residential energy use amounted to 1392 petajoules; the addition of agriculture energy use would bring the amount up to 1587 petajoules.

7.3 Factors Influencing Growth in Commercial Energy Use from 1990 to 1994

Commercial sector energy use increased by 72 petajoules from 1990 to 1994, an average annual increase of 2.0 per cent. An analysis of the impact of major influential factors on commercial energy use over this period is presented in Figure 7.4.

Figure 7.4
Factors Influencing Growth in Commercial Energy Use, 1990 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

As for other factors, growth in *activity* (measured as floor space) was the major force driving the increase in energy use in the commercial sector. Had only *activity* changed from 1990 to 1994 and all other factors remained at their 1990 levels, commercial energy use would have increased by 72 petajoules (which is equivalent to the increase in energy use actually observed over the period).

Structure and *weather* also contributed, although in a minor way, to the increase in commercial sector energy use. There was a shift in commercial sector *activity* towards more energy-intensive building types, which contributed to increase energy use by 4 petajoules.

As for the residential sector, the difference in *weather* between 1994 and 1990 contributed to the increase in commercial energy use. If *weather* had been the same in 1994 as it was in 1990, commercial energy use would have been 9 petajoules lower in 1994 than it actually was.

Commercial sector *energy intensity* was the only factor to cause a decline in energy use in the sector. Had *energy intensity* remained constant at its 1990 level through 1994, energy use would have been 13 petajoules higher in 1994 (i.e., commercial energy use would have grown by 85 petajoules rather than 72 petajoules).

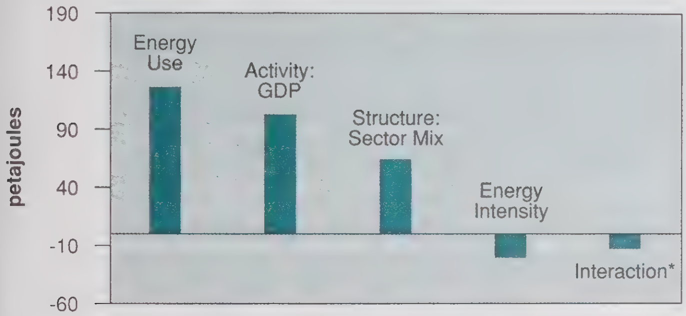
The decline in commercial sector *energy intensity* resulted partly from the penetration of more energy-efficient buildings. Recent revisions to the energy efficiency component of provincial and municipal building codes have led to improvements in the energy efficiency of new construction. For example, the Vancouver building code now requires new construction to meet energy efficiency levels set out in the ASHRAE 90.1 standards, which are significantly more energy efficient than construction standards in other jurisdictions.

Attitudes toward energy conservation also affect unit energy use. In a recent survey of the Saskatchewan commercial sector, conducted by the Saskatchewan Energy Conservation and Development Authority, 75 per cent of respondents said that they routinely turned off lights and lowered thermostat settings when their buildings were unoccupied. The survey also shows that 40 per cent of respondents had made energy efficiency improvements in their buildings in the past five years.

7.4 Factors Influencing Growth in Industrial Energy Use from 1990 to 1994

The evolution of industrial sector energy use from 1990 to 1994 and the contribution of *activity* growth, *structure* shifts and *energy intensity* to its change is illustrated in Figure 7.5. Industrial energy use increased by 128 petajoules over the period (for an average annual increase of 1.2 per cent). As for other factors, the change in industrial energy use was driven by growth in the level of *activity* (measured as gross domestic product), which was partly offset by a decline in *energy intensity*.

Figure 7.5
Factors Influencing Growth in Industrial Energy Use, 1990 - 1994 (petajoules)



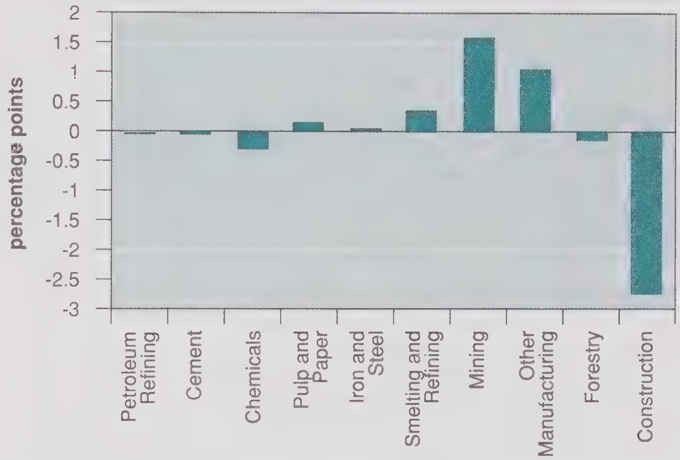
* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

The growth in industrial sector *activity* contributed to an increase in energy use of 93 petajoules, 73 per cent of the total increase in the sector's energy use.

Another factor contributing to increased energy use was the change in the distribution of *activity* among industries (*structure*). Figure 7.6 presents data on the changes in the shares of selected industries in total gross domestic product. Note that at the bottom of the figure, the *energy intensity* of each industry in 1994 is indicated.

From 1990 to 1994, the share of industrial *activity* accounted for by the more energy-intensive industries (petroleum refining, cement, chemicals, pulp and paper, iron and steel, smelting and refining, and mining) increased by 1.8 percentage points, whereas the share accounted for by the less energy-intensive industries (other manufacturing, forestry, and construction) declined. This structural shift contributed to an increase of 69 petajoules in industrial energy use during the period.

Figure 7.6
Changes in Sectoral Shares of Industrial Activity, 1990 - 1994 (percentage points)



1994 Energy Intensity (MJ/$):	Petroleum Refining	Cement	Chemicals	Pulp and Paper	Iron and Steel	Smelting and Refining	Mining	Other Manufacturing	Forestry	Construction
	148	131	103	90	89	76	17	6	4	1

Sector-specific *energy intensities* declined from 1990 to 1994. Without this decline, industrial energy use would have been 21 petajoules higher in 1994 than it actually was.

The above noted decline was mitigated by a trend in the pulp and paper industry, which accounts for 30 per cent of industrial energy use, away from the use of fossil fuels and towards wood waste and pulping liquor. Since the energy content of wood waste is less than that of fossil fuels, more wood waste and pulping liquor is needed to meet the same level of end-use requirements. The share of wood waste and pulping liquor increased 3 percentage points to 52 per cent of energy use in the pulp and paper industry in 1994.

Over the 1990 to 1994 period, the sector-specific *energy intensities* declined in the face of decreasing capacity utilization rates. Declining capacity utilization rates tend to exert upward pressure on *energy intensity*, since energy use usually cannot be decreased to the same extent as production levels. This is because a given level of fixed energy requirements must be met at all times.

One industry that made significant energy efficiency improvements during this period is the smelting and refining industry (the fastest-growing sub-sector since 1990). The two most energy-efficient aluminum smelters currently in use began operating after 1990.

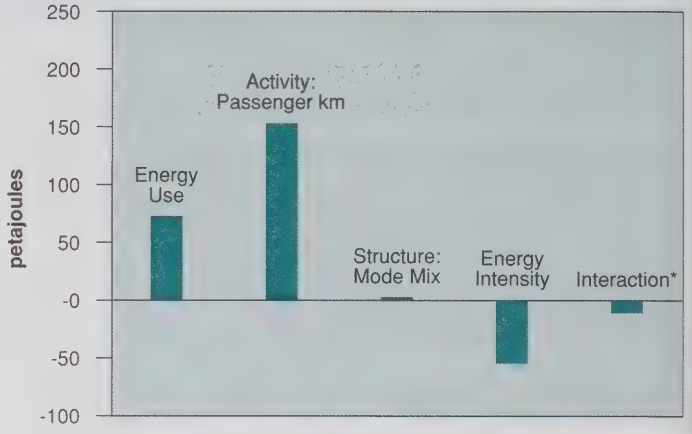
7.5 Factors Influencing Growth in Transportation Energy Use from 1990 to 1994

In this section, we discuss developments in the passenger travel and the freight transport sectors separately.

Passenger travel

From 1990 to 1994, passenger transportation energy use increased at an average annual rate of 1.5 per cent for a total increase of 85 petajoules.[3,4] *Activity*[5] (measured as passenger kilometres), which grew at an average rate of 3.2 per cent per year, had a marked effect on energy use. Had all other factors except *activity* remained constant at 1990 levels, energy use in this sector would have increased by 153 petajoules, almost twice the actual increase.

Figure 7.7
Factors Influencing Growth in Passenger Transportation Energy Use, 1990 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

Underlying the strong growth in passenger-kilometres was an average increase of 1.2 per cent per year in the stock of light passenger vehicles and an average annual increase of more than 1.7 per cent in average distance travelled.

The change in *energy intensity* during the period helped lessen the effect on energy use of *activity* and *structure* by about 58 petajoules. Despite a real gasoline price decrease, *energy intensity* declined at an average annual rate of 2 per cent per year because of the penetration of more fuel-efficient vehicles in the stock of light vehicles. The average fuel-efficiency improvement of new small cars was 1.8 per cent per year. Modest fuel-efficiency gains were made with new large cars and new light trucks (0.4 per cent per year).

3 Note that two components of the transportation sector were not included in the factorization analysis. These two segments were excluded for lack of suitable activity measures to use in the factorization methodology.

In the passenger transportation sector, non-airline (i.e., commercial/institutional and public administration) air transport was excluded. This segment, which represented 28 petajoules in 1994, declined by 11 petajoules from 1990 to 1994. This change in passenger transport energy use is not explained in the factorization of energy use in this sector.

Similarly, in the freight transport sector, marine transportation was excluded. This segment, which represented 106 petajoules in 1994, declined by 2 petajoules from 1990 to 1994.

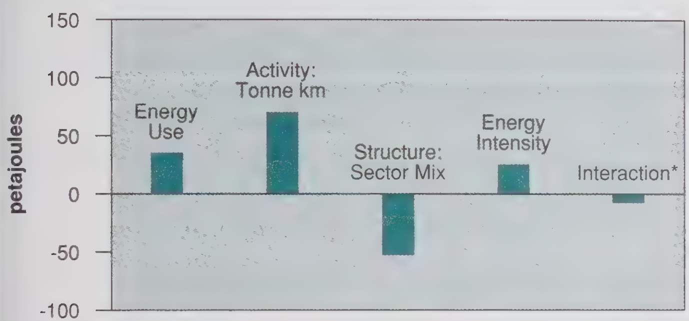
4 The change in energy use presented in Figure 7.7 is the actual change for this sector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis excludes the non-airline segment and uses a motor gasoline equivalency value for all fuels.

5 Passenger transportation activity (passenger-kilometres) does not include the non-airline segment.

Freight Transport

From 1990 to 1994, freight transportation energy use increased at an average annual rate of 1.3 per cent for a total increase of 36 petajoules.[6] *Activity*[7] (measured as tonne-kilometres), which grew at an average rate of 3.1 per cent per year, had a marked effect on energy use. Had all other factors except *activity* remained constant at 1990 levels, energy use in this sector would have increased by 70 petajoules.

Figure 7.8
Factors Influencing Growth in Freight Transportation Energy Use, 1990 - 1994 (petajoules)



* For an explanation of this term, see box titled "The Interaction Effect" in Chapter 2.

Changes in the *structure* of freight sector *activity* and in *energy intensity* also played a significant role in the evolution of the sector's energy use. First, the shift in freight *activity* towards rail and away from road contributed to keeping energy use down. The *energy intensity* of trucks is significantly larger than that of trains. Had the *structure* of freight *activity* remained the same in 1994 as it was in 1990, energy use would have been 52 petajoules higher in 1994.

Energy intensity, on the other hand caused energy use to increase. Had *energy intensity* remained at its 1990 level through 1994, energy use would have been 28 petajoules lower in 1994.

7.6 Conclusion

Between 1990 and 1994, *energy intensity* declined in all sectors of the Canadian economy except for freight transport. During the same period, however, secondary energy use and associated carbon dioxide emissions increased.

Secondary energy use increased because of the influence of *activity* growth, *structure shifts* and *weather* on energy use. In general, the increase in human and economic *activity* was the most significant force driving energy use upward in each sector of the economy over the period.

In the end, while energy efficiency led to declines in *energy intensity* and ultimately the mitigation of increases in energy use and carbon dioxide emissions, other factors more than offset this impact, resulting in a continued increase of secondary energy use. It is important to note, however, that in the absence of energy efficiency improvements and the ensuing energy-intensity declines, secondary energy use would have increased by 123 petajoules more than it actually did from 1990 to 1994.

[6] The change in energy use presented in Figure 7.8 is the actual change for this sector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis excludes the marine segment and uses a motor gasoline equivalency value for all on-road fuels other than diesel.

[7] See footnotes 2 and 3 in Chapter 6.

Data Presented in Report

Table A-1.2
Factors Influencing Growth in Carbon Dioxide Emissions, 1984 - 1994 (average annual growth rate – per cent)

Factors	1984 - 1994
• CO_2	1.29
• CO_2/Fossil	-0.14
• Fossil/Primary	-0.71
• Primary/Secondary	0.67
• Secondary	1.47

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-1.3
Factors Influencing Growth in Carbon Dioxide Emissions, 1990 - 1994 (average annual growth rate – per cent)

Factors	1990 - 1994
• CO_2	1.15
• CO_2/Fossil	-0.30
• Fossil/Primary	-1.00
• Primary/Secondary	1.11
• Secondary	1.34

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1994 IV (Cat 57-003) Quarterly, Ottawa, Ontario, August 1990 and July 1995.

Table A-2.1
Secondary Energy Use by Sector, 1984 and 1994 (petajoules)

Factors	1984	1994
• Secondary (All Sectors)	6 319	7 314
• Residential & Agriculture	1 369	1 587
• Commercial	823	936
• Industrial	2 450	2 841
• Transport	1 677	1 949

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-3.1
Distribution of Households by Type of Dwelling in 1994 (per cent)

Types of Dwelling	1994
• Single Detached	57.4
• Single Attached	9.8
• Apartments	30.6
• Mobile Homes	2.2

Source: • Statistics Canada, *Household Facilities and Equipment*, 1994 (Cat. 64-202) Annual, Ottawa, Ontario, October 1994.

Table A-3.2
Distribution of Residential Energy Use by Type of Dwelling in 1994 (per cent)

Types of Dwelling	1994
• Single Detached	65.5
• Single Attached	8.6
• Apartments	24.1
• Mobile Homes	1.8

Sources: • Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, 1994 (Cat. 64-202) Annual, Ottawa, Ontario, October 1994.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-3.3
Distribution of Residential Energy Use by Fuel in 1994 (per cent)

Fuels	1994
• Natural Gas	47.3
• Oil Products	11.8
• Electricity	34.0
• Other Fuels	6.9

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-3.4
Distribution of Residential Energy Use by End Use in 1994 (per cent)

End-uses	1994
• Space Heating	61.8
• Water Heating	22.0
• Space Cooling	0.4
• Appliances	15.8

Sources: • Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-3.5
Residential Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)

Years	Energy Use	Activity: Households	Energy Intensity	Weather	Weather Adjusted Energy Intensity
• 1984	1.00	1.00	1.00	1.00	1.00
• 1985	1.04	1.02	1.03	1.04	1.01
• 1986	1.02	1.03	0.98	0.99	0.99
• 1987	0.97	1.05	0.92	0.92	0.95
• 1988	1.05	1.07	0.98	0.99	0.98
• 1989	1.12	1.10	1.02	1.05	0.99
• 1990	1.09	1.12	0.98	0.95	1.00
• 1991	1.06	1.15	0.93	0.96	0.95
• 1992	1.07	1.17	0.92	1.02	0.94
• 1993	1.14	1.19	0.96	1.04	0.95
• 1994	1.16	1.21	0.96	1.01	0.95

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, various issues, Toronto, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-3.6
Residential Energy Fuel Shares, 1984 and 1994 (per cent)

Fuels	1984	1994
• Natural Gas	42.1	47.3
• Oil Products	18.0	11.8
• Electricity	30.3	34.0
• Other Fuels	9.6	6.9

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-3.7
Residential Energy End-use Shares, 1984 and 1994 (per cent)

End-uses	1984	1994
• Space Cooling	0.2	0.4
• Appliances	14.8	15.8
• Water Heating	18.7	22.0
• Space Heating	66.3	61.8

Sources: • Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-3.8
Factors Influencing Growth in Residential Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	190.41
• Activity: Households	246.92
• Weather	7.81
• Structure: End-Use Mix	0.30
• Energy Intensity (weather adjusted)	-54.22
• Interaction	-10.40

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, various issues, Toronto, Ontario.
• Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-3.9
Factors Influencing Growth in Residential Space Heating Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	63.77
• Activity: Households	163.65
• Weather	7.18
• Energy Intensity (weather adjusted)	-71.76
• Interaction	-35.30

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, various issues, Toronto, Ontario.
• Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-3.10
Housing Stock by Vintage, 1984 and 1994 (per cent)

Vintages	1984	1994
• Pre 1945	26.7	20.9
• 1946-1960	17.7	14.3
• 1961-1977	42.1	33.5
• 1978-1994	13.5	31.3

Sources: • Statistics Canada, *Household Facilities and Equipment*, revised estimates for 1984 and 1994, (Cat. 64-202) Annual, Ottawa, Ontario, March 1989 and October 1994.
• Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.

Table A-3.11
Average Heated Living Area per Dwelling by Vintage in 1993 (square feet)

Vintages	Average Heated Area
• Pre-1941	1 299
• 1941-1960	1 174
• 1961-1977	1 287
• 1978-1982	1 374
• After 1982	1 535

Source: • Natural Resources Canada, *1993 Survey of Household Energy Use National Results*, Ottawa, Ontario, November 1994.

Table A-3.12
Factors Influencing Growth in Residential Appliance Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	42.01
• Activity: Households	36.66
• Appliance Penetration	9.06
• Energy Intensity	-28.37
• Interaction	24.65

Sources: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.

Table A-3.13
Penetration Rates for Household Appliances, 1984 and 1994 (average number per household)

Appliances	1984	1994
• Refrigerators	1.16	1.18
• Freezers	0.56	0.59
• Dishwashers	0.35	0.46
• Clothes Dryers	0.67	0.75
• Clothes Washers	0.77	0.79
• Ranges	0.98	0.98
• Video Cassette Recorders	0.13	0.79
• Compact Disc Players	n.a.	0.41
• Home Computers	0.03	0.25
• Microwave Ovens	0.16	0.81

Source: • Statistics Canada, *Household Facilities and Equipment*, revised estimates for 1984 and 1994, (Cat. 64-202) Annual, Ottawa, Ontario, March 1989 and October 1994.

Table A-3.14
Energy Efficiency Trends of Appliances, 1984 and 1994 (kWh per year)

Appliances	1984	1994
• Refrigerators	1 457	690
• Freezers	813	380
• Electric Ranges	790	670
• Dishwashers	1 213	896
• Clothes Washers	1 243	1 126
• Electric Clothes Dryers	1 214	921

Source: • Natural Resources Canada, *EnerGuide Directories* 1983, 1985 and 1994, Ottawa, Ontario.

Note: Estimates for 1984 were arrived at by interpolating data for 1983 and 1985.

Table A-3.15
Distribution of Households by Water Heating Fuel, 1984 and 1994 (per cent)

Fuels	1984	1994
• Natural Gas	49.8	57.2
• Oil	11.6	8.8
• Electricity	37.3	33.5
• Other	1.3	0.5

Source: • Statistics Canada, *Household Facilities and Equipment*, revised estimates for 1984 and 1994, (Cat. 64-202) Annual, Ottawa, Ontario, March 1989 and October 1994.

Table A-3.16
Penetration Rates for Air Conditioners, 1984 and 1994 (per cent of households)

Air Conditioners	1984	1994
• Air Conditioning	16.7	26.8
• Central	7.6	17.2
• Room	9.0	9.5

Source: • Statistics Canada, *Household Facilities and Equipment*, revised estimates for 1984 and 1994, (Cat. 64-202) Annual, Ottawa, Ontario, March 1989 and October 1994.

Table A-4.1
Distribution of Commercial Floor Space by Building Type in 1994 (per cent)

Building Types	1994
• School	15.7
• Health	7.1
• Religious	1.8
• Other Institution	4.1
• Office	25.7
• Retail	23.6
• Hotel/Restaurant	6.6
• Recreation	6.2
• Warehouse	9.2

Source: • Informetrica Limited, *Historical Estimates of Commercial Floor Space*, 1994 Database Update, Ottawa, Ontario, March 2, 1995.

Table A-4.2
Distribution of Commercial Energy Use by Building Type in 1994 (per cent)

Building Types	1994
• School	15.5
• Health	11.3
• Religious	1.3
• Other Institution	3.9
• Office	23.8
• Retail	23.5
• Hotel/Restaurant	9.6
• Recreation	6.2
• Warehouse	4.9

Sources: • Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-4.3
Distribution of Commercial Energy Use by Fuel in 1994 (per cent)

Fuels	1994
• Electricity	43.3
• Natural Gas	42.3
• Oil Products	6.4
• Other Fuels	8.0

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-4.4
Distribution of Commercial Energy Use by End Use in 1994 (per cent)

End-uses	1994
• Lighting	14.3
• Space Cooling	4.5
• Auxiliary Motor	12.0
• Auxiliary Equipment	6.6
• Space Heating	55.3
• Water Heating	7.3

Sources: • Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-4.5
Commercial Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)

Years	Commercial Energy Use	Activity: Floor Space	Intensity
1984	1.00	1.00	1.00
1985	1.00	1.04	0.96
1986	1.01	1.08	0.94
1987	0.95	1.13	0.84
1988	1.03	1.18	0.87
1989	1.08	1.24	0.87
1990	1.05	1.30	0.81
1991	1.06	1.34	0.79
1992	1.08	1.37	0.79
1993	1.14	1.39	0.82
1994	1.14	1.41	0.81

Sources: • Informetrica Limited, *Historical Estimates of Commercial Floor Space*, 1994 Database Update, Ottawa, Ontario, March 2, 1995.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-4.6
Commercial Energy Fuel Shares, 1984 and 1994 (per cent)

Fuels	1984	1994
• Electricity	35.8	43.3
• Natural Gas	44.3	42.3
• Oil Products	14.3	6.4
• Other Fuels	5.6	8.0

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-4.7
Commercial Energy End-use Shares, 1984 and 1994 (per cent)

End-uses	1984	1994
• Lighting	11.9	14.3
• Space Cooling	3.9	4.5
• Auxiliary Motor	10.1	12.0
• Auxiliary Equipment	5.4	6.6
• Space Heating	60.6	55.3
• Water Heating	8.1	7.3

Sources: • Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada* 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-4.8
Factors Influencing Growth in Commercial Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy	113.57
• Activity	337.11
• Weather	0.36
• Structure	7.54
• Intensity (weather adjusted)	-165.90
• Interaction	-65.54

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days above 21.0°C, various issues, Toronto, Ontario.
• Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, various issues, Toronto, Ontario.
• Informetrica Limited, *Historical Estimates of Commercial Floor Space*, 1994 Database Update, Ottawa, Ontario, March 2, 1995.
• Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-5.1
Distribution of Industrial Activity by Sector in 1994 (per cent)

Sectors	1994
• Mining	14.8
• Construction	19.2
• Forestry	1.8
• Pulp and Paper	6.1
• Iron and Steel	1.7
• Smelting and Refining	1.9
• Cement	0.2
• Chemicals	1.7
• Petroleum Refining	1.4
• Other Manufacturing	51.2

Source: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.

Table A-5.2
Distribution of Industrial Energy Use by Sector in 1994 (per cent)

Sectors	1994
• Mining	13.9
• Construction	1.2
• Forestry	0.4
• Pulp and Paper	29.2
• Iron and Steel	8.3
• Smelting and Refining	7.6
• Cement	1.7
• Chemicals	9.2
• Petroleum Refining	10.9
• Other Manufacturing	17.6

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-5.3
Distribution of Industrial Energy Use by Fuel in 1994 (per cent)

Fuels	1994
• Electricity	25.1
• Natural Gas	33.8
• Oil Products	18.3
• Coal, Coke and Coke Oven Gas	5.8
• Other Fuels (incl. Wood Waste)	17.0

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-5.4
Distribution of Industrial Energy Use by End Use for Selected Sectors in 1994 (per cent)

Sectors	Auxiliary Generation	Steam and Heat	Process
• Pulp and Paper	20	64	16
• Iron and Steel	8	5	87
• Chemicals	16	27	57
• Petroleum Refining	5	21	74
• Cement	8	0	92
• Mining	16	23	61

Source: • Simon Fraser University, Energy Research Group, Intra-Sectoral Technology Use Model for Industry, Burnaby, British Columbia.

Table A-5.5
Industrial Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)

Years	Energy Use	Activity: GDP	Intensity
1984	1.00	1.00	1.00
1985	1.02	1.06	0.97
1986	1.05	1.06	0.99
1987	1.10	1.12	0.98
1988	1.15	1.18	0.98
1989	1.15	1.19	0.96
1990	1.11	1.16	0.95
1991	1.10	1.09	1.01
1992	1.10	1.09	1.01
1993	1.12	1.13	0.99
1994	1.16	1.20	0.97

Sources: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.
• Statistics Canada, *Gross Domestic Product by Industry*, 1961 to 1985 (Cat. 15-512) occasional, Ottawa, Ontario, January 1991.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-5.6
Industrial Energy Fuel Shares, 1984 and 1994 (per cent)

Fuels	1984	1994
• Electricity	23.5	25.1
• Natural Gas	29.7	33.8
• Oil Products	21.7	18.3
• Coal, Coke and Coke Oven Gas	9.5	5.8
• Other Fuels (incl. Wood Waste)	15.6	17.0

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-5.7
Industrial Energy Sector Shares, 1984 and 1994 (per cent)

Sectors	1984	1994
• Mining	11.3	13.9
• Construction	1.5	1.2
• Forestry	0.5	0.4
• Pulp and Paper	26.6	29.2
• Iron and Steel	11.4	8.3
• Smelting and Refining	6.8	7.6
• Cement	1.9	1.7
• Chemicals	9.5	9.2
• Petroleum Refining	12.7	10.9
• Other Manufacturing	17.8	17.6

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-5.8
Factors Influencing Growth in Industrial Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	390.91
• Activity: GDP	489.50
• Structure: Sector Mix	-53.60
• Energy Intensity	-29.11
• Interaction	-15.88

Sources: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.
• Statistics Canada, *Gross Domestic Product by Industry*, 1961 to 1985 (Cat. 15-512) Occasional, Ottawa, Ontario, January 1991.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-5.9
Changes in Energy Intensity by Industrial Sector, 1984 - 1994 (per cent)

Sectors	1984 - 1994
• Mining	13.5
• Construction	-16.1
• Forestry	-14.0
• Pulp and Paper	11.1
• Iron and Steel	-13.5
• Smelting and Refining	-15.4
• Cement	-2.6
• Chemicals	2.4
• Petroleum Refining	-14.7
• Other Manufacturing	-6.1

Sources: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.
• Statistics Canada, *Gross Domestic Product by Industry*, 1961 to 1985 (Cat. 15-512) Occasional, Ottawa, Ontario, January 1991.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-6.1
Distribution of Passenger-Kilometres by Mode in 1994 (per cent)

Modes	1994
• Road – Light Vehicles	87.3
• Rail	0.2
• Aviation	10.7
• Road – Buses	1.8

Sources: • Canada, Royal Commission on National Passenger Transportation, Hyndman, Louis D., Direction: *The Final Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
• Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Aviation Statistics Centre*, Service Bulletin, various issues (Cat. 51-004) Monthly, Ottawa, Ontario.
• Statistics Canada, *Passenger Bus and Urban Transit Statistics*, (Cat. 53-215) Annual, Ottawa, Ontario, December 1995.
• Statistics Canada, *Rail in Canada*, 1994 (Cat. 52-216) Annual, Ottawa, Ontario, December 1995.

Table A-6.2
Distribution of Tonne-Kilometres by Mode in 1994 (per cent)

Modes	1994
• Road – Trucks	16.4
• Rail	83.6

Sources: • Statistics Canada, *Rail in Canada*, 1994 (Cat. 52-216) Annual, Ottawa, Ontario, December 1995.
• Statistics Canada, *Trucking in Canada*, 1994 (Cat. 53-222) Annual, Ottawa, Ontario, December 1995.

Table A-6.3
Distribution of Passenger Transportation Energy Use by Mode in 1994 (per cent)

Modes	1994
• Road – Light Vehicles	84.5
• Rail	0.2
• Aviation	13.6
• Road – Busses	1.7

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-6.4
Distribution of Passenger Transportation Energy Use by Fuel in 1994 (per cent)

Fuels	1994
• Motor Gasoline	81.6
• Diesel	3.0
• Alternative Transportation Fuels	1.8
• Aviation Fuels	13.6

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995.

Table A-6.5
Passenger Transportation Energy Use, Intensity and Activity, 1984 - 1994 (Index 1984 = 1.0)

Years	Energy Use	Activity: passenger km	Energy Intensity
1984	1.00	1.00	1.00
1985	1.02	1.05	0.97
1986	1.03	1.09	0.95
1987	1.05	1.14	0.93
1988	1.10	1.20	0.91
1989	1.12	1.25	0.89
1990	1.09	1.23	0.88
1991	1.04	1.20	0.87
1992	1.08	1.25	0.86
1993	1.11	1.31	0.85
1994	1.16	1.40	0.83

Sources:
- Canada, Royal Commission on National Passenger Transportation, Hyndman, Louis D., Direction: *The Final Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002) Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre*, Service Bulletin, various issues (Cat. 51-004) Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, various issues, (Cat. 53-215), Annual, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, various issues, (Cat. 52-216) Annual, Ottawa, Ontario.

Table A-6.6
Passenger Transportation Energy Fuel Shares, 1984 and 1994 (per cent)

Fuels	1984	1994
• Motor Gasoline	81.5	81.6
• Diesel	3.5	3.0
• Alternative Transportation Fuels	0.9	1.8
• Aviation Fuels	14.1	13.6

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-6.7
Passenger Transportation Energy Mode Shares, 1984 and 1994 (per cent)

Modes	1984	1994
• Road – Light Vehicles	83.7	84.5
• Rail	0.6	0.2
• Aviation	14.1	13.6
• Road – Buses	1.6	1.7

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-6.8
Factors Influencing Growth in Passenger Transportation Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	170.64
• Activity: Passenger km	424.12
• Structure: Mode Mix	6.17
• Energy Intensity	-178.18
• Interaction	-76.07

Sources: • Canada, Royal Commission on National Passenger Transportation, Hyndman, Louis D., Direction: *The Final Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
• Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Aviation Statistics Centre*, Service Bulletin, various issues (Cat. 51-004) Monthly, Ottawa, Ontario.
• Statistics Canada, *Passenger Bus and Urban Transit Statistics*, various issues, (Cat. 53-215) Annual, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Rail in Canada*, various issues, (Cat. 52-216) Annual, Ottawa, Ontario.

Table A-6.9
Factors Influencing Growth in Light Vehicles Passenger Transportation Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	154.05
• Activity: Passenger km	390.03
• Structure: Vehicle Mix	-5.30
• Energy Intensity	-170.70
• Interaction	-58.52

Sources: • Canada, Royal Commission on National Passenger Transportation, Hyndman, Louis D., Direction: *The Final Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
• Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-6.10
Economic Indicators, 1984 - 1994 (index 1984 = 1.0)

Years	Households	People per Household	Cars per Household	Real Income per Household
1984	1.00	1.00	1.00	1.00
1985	1.02	0.99	1.02	1.01
1986	1.03	0.99	1.04	1.02
1987	1.06	0.98	1.05	1.02
1988	1.07	0.98	1.07	1.06
1989	1.10	0.97	1.08	1.08
1990	1.12	0.97	1.08	1.07
1991	1.15	0.95	1.06	1.03
1992	1.17	0.95	1.06	1.02
1993	1.19	0.95	1.06	1.01
1994	1.21	0.94	1.05	1.00

Sources: • Natural Resources Canada, *Interfuel Substitution Demand Model*, Ottawa, Ontario.
• Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.

Table A-6.11
Distribution of the Stock of Passenger Vehicles by Class, 1984 - 1994 (per cent)

Years	Small Cars	Large Cars	Light Duty Trucks
1984	45.8	40.4	13.8
1985	46.8	38.8	14.5
1986	47.8	37.5	14.7
1987	48.4	35.9	15.7
1988	49.0	34.9	16.1
1989	49.4	33.9	16.7
1990	50.7	33.4	15.9
1991	51.3	33.1	15.6
1992	51.6	32.6	15.8
1993	51.3	32.0	16.7
1994	50.4	31.3	18.3

Source: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.

Table A-6.12
Road Transportation Price Indicators, 1984 - 1994 (Index 1984 = 1.0)

Years	Real Gasoline Price	Real Car Operating Cost
1984	1.00	1.00
1985	1.02	1.00
1986	0.86	0.94
1987	0.87	0.94
1988	0.83	0.93
1989	0.87	0.94
1990	0.94	0.98
1991	0.87	0.98
1992	0.82	0.97
1993	0.78	0.97
1994	0.77	0.99

Sources: • Canadian Automobile Association, *Autopinion*, various issues, Ottawa, Ontario.
• Natural Resources Canada, *Interfuel Substitution Demand Model*, Ottawa, Ontario.

Table A-6.13
Trends in New Vehicle Fuel Economy, 1984 - 1994 (litres per 100 km)

Years	Small Cars	Large Cars	Motor Gasoline Light Trucks
1984	7.47	9.81	11.39
1985	7.25	9.79	11.35
1986	7.46	9.92	10.92
1987	7.62	9.97	10.83
1988	7.47	9.40	10.78
1989	7.80	9.64	11.16
1990	8.00	9.79	11.10
1991	7.98	9.44	10.69
1992	7.57	9.49	10.84
1993	7.66	9.60	10.80
1994	7.44	9.64	11.27

Source: Transport Canada and Natural Resources Canada, *Fuel Consumption Guide*, various issues, Ottawa, Ontario.

Table A-6.14
Distribution of Freight Transportation Energy Use by Mode in 1994 (per cent)

Modes	1994
• Road – Trucks	71.7
• Marine	15.6
• Rail	12.7

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, July 1995
- Statistics Canada, *Rail in Canada*, 1994 (Cat. 52-216) Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Shipping in Canada*, 1994 (Cat. 54-205) Annual, Ottawa, Ontario, November 1995.
- Statistics Canada, *Trucking in Canada*, 1994 (Cat. 53-222) Annual, Ottawa, Ontario, December 1995.

Table A-6.15
Distribution of Freight Transportation Energy Use by Fuel in 1994 (per cent)

Fuels	1994
• Motor Gasoline	21.1
• Diesel	67.2
• Other Fuels (Propane, Natural Gas and LFO)	2.9
• Heavy Fuel Oil	8.8

Source:s • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, various issues (Cat. 52-216) Annual, Ottawa, Ontario.
- Statistics Canada, *Shipping in Canada*, various issues (Cat. 54-205) Annual, Ottawa, Ontario.
- Statistics Canada, *Trucking in Canada*, various issues (Cat. 53-222) Annual, Ottawa, Ontario.

Table A-6.16
Freight Transportation Energy Use, Intensity and Activity, 1984 - 1994 (index 1984 = 1.0)

Years	Energy Use	Activity: Tonne km	Energy Intensity
1984	1.00	1.00	1.00
1985	0.99	0.96	1.03
1986	0.97	0.99	0.98
1987	1.05	1.09	0.96
1988	1.13	1.11	1.02
1989	1.14	1.02	1.12
1990	1.11	1.03	1.09
1991	1.09	1.04	1.05
1992	1.08	1.01	1.07
1993	1.09	1.04	1.05
1994	1.18	1.16	1.01

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, various issues (Cat. 52-216) Annual, Ottawa, Ontario.
- Statistics Canada, *Shipping in Canada*, various issues (Cat. 54-205) Annual, Ottawa, Ontario.
- Statistics Canada, *Trucking in Canada*, various issues (Cat. 53-222) Annual, Ottawa, Ontario.

Table A-6.17
Freight Transportation Energy Fuel Shares, 1984 and 1994 (per cent)

Fuels	1984	1994
• Motor Gasoline	34.1	21.1
• Diesel	56.2	67.2
• Other Fuels (Propane, Natural Gas & LFO)	1.0	2.9
• Heavy Fuel Oil	8.7	8.8

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1985 and July 1995.

Table A-6.18
Freight Transportation Energy Mode Shares, 1984 and 1994 (per cent)

Modes	1984	1994
• Road – Trucks	71.4	71.7
• Marine	14.8	15.6
• Rail	13.8	12.7

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1984 IV and 1994 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1985 and July 1995.
• Statistics Canada, *Rail in Canada*, 1984 and 1994 (Cat. 52-216) Annual, Ottawa, Ontario, December 1995.
• Statistics Canada, *Shipping in Canada*, 1984 and 1994 (Cat. 54-205) Annual, Ottawa, Ontario, November 1995.
• Statistics Canada, *Trucking in Canada*, 1984 and 1994 (Cat. 53-222) Annual, Ottawa, Ontario, July 1986 and December 1995.

Table A-6.19
Factors Influencing Growth in Freight Transportation Energy Use, 1984 - 1994 (petajoules)

Factors	1984 - 1994
• Energy Use	101.94
• Activity: Tonne km	78.71
• Structure: Mode Mix	47.95
• Energy Intensity	-39.88
• Interaction	-3.71

Sources: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Rail in Canada*, various issues (Cat. 52-216) Annual, Ottawa, Ontario.
• Statistics Canada, *Trucking in Canada*, various issues (Cat. 53-222) Annual, Ottawa, Ontario.
• Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.

Table A-7.1
Secondary Energy Use by Sector, 1990 and 1994 (petajoules)

Factors	1990	1994
• Secondary (All Sectors)	6 932	7 314
• Residential & Agriculture	1 515	1 587
• Commercial	864	936
• Industrial	2 713	2 841
• Transport	1 839	1 949

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV (Cat. 57-003) Quarterly, Ottawa, Ontario, August 1990.

Table A-7.2
Factors Influencing Growth in Residential Energy Use, 1990 - 1994 (petajoules)

Factors	1990 - 1994
• Energy Use	81.41
• Activity: Households	103.92
• Weather	40.02
• Structure: End-Use Mix	0.14
• Energy Intensity	-59.19
• Interaction	-3.47

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days above 21.0°C, Toronto, Ontario.
• Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, Toronto, Ontario.
• Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Household Facilities and Equipment*, various issues, (Cat. 64-202) Annual, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-7.3
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1994 (thousands)

Efficiency	1990	1994
• Normal Efficiency	87	0
• Mid Efficiency	22	114
• High Efficiency	30	58
• Total	139	172

Source: Canadian Gas Association, *Canadian Gas Facts 1995*, North York, Ontario, September 1995.

Table A-7.4
Factors Influencing Growth in Commercial Energy Use, 1990 - 1994 (petajoules)

Factors	1990 - 1994
• Energy Use	72.24
• Activity: Floor Space	72.03
• Weather	9.42
• Structure: Building Type	3.90
• Energy Intensity	-12.81
• Interaction	-0.30

Sources: • Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days above 21.0°C, Toronto, Ontario.
• Environment Canada, Atmospheric Environment Service, Monthly Summary of Degree-Days below 18.0°C, Toronto, Ontario.
• Informetrica Limited, *Historical Estimates of Commercial Floor Space*, 1994 Database Update, Ottawa, Ontario, March 2, 1995.
• Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-7.5
Factors Influencing Growth in Industrial Energy Use, 1990 - 1994 (petajoules)

Factors	1990 - 1994
• Energy Use	127.80
• Activity: GDP	92.92
• Structure: Sector Mix	69.13
• Energy Intensity	-20.65
• Interaction	-13.60

Sources: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-7.6
Changes in Sectoral Shares of Industrial Activity, 1990 - 1994 (percentage points)

Sectors	1990 - 1994
• Mining	1.60
• Construction	-2.72
• Forestry	-0.15
• Pulp and Paper	0.17
• Iron and Steel	0.07
• Smelting and Refining	0.36
• Cement	-0.06
• Chemicals	-0.30
• Petroleum Refining	-0.03
• Other Manufacturing	1.06

Source: • Statistics Canada, *Gross Domestic Product by Industry*, June 1995 (Cat. 15-001) Monthly, Ottawa, Ontario, September 1995.

Table A-7.7
Factors Influencing Growth in Passenger Transportation Energy Use, 1990 - 1994 (petajoules)

Factors	1990 - 1994
• Energy Use	74.64
• Activity: Passenger km	152.82
• Structure: Mode Mix	1.15
• Energy Intensity	-57.74
• Interaction	-10.27

Sources: • Canada, Royal Commission on National Passenger Transportation, Hyndman, Louis D., Direction: *The Final Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
• Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.

Table A-7.8
Factors Influencing Growth in Freight Transportation Energy Use, 1990 - 1994 (petajoules)

Factors	1990 - 1994
• Energy Use	35.49
• Activity: Tonne km	70.30
• Structure: Mode Mix	-51.78
• Energy Intensity	27.55
• Interaction	-8.54

Sources: • Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003) Quarterly, Ottawa, Ontario.
• Statistics Canada, *Rail in Canada*, various issues (Cat. 52-216) Annual, Ottawa, Ontario.
• Statistics Canada, *Trucking in Canada*, various issues (Cat. 53-222) Annual, Ottawa, Ontario.

Methodology and Data Sources for Factorization Analysis

1 Introduction

This appendix briefly describes the key elements of methodology used in this study to analyze secondary energy end-use trends in the Canadian economy as a whole and in each of the four end-use sectors. Four important objectives motivated the choice of methodology:[1]

- Interpretation of the index is straightforward.
- The same index can be applied to all sectors and sub-sectors, so that all can be interpreted similarly.
- Data is available with which to calculate the indexes.
- The index is theoretically sound.

In the simplest of terms, an energy efficiency index is a statistical indicator that measures energy use, taking into account changes in energy intensity, structural influences, and economic or physical activity. Such indicators can be applied to measure energy consumption at the economy-wide level, and in individual sectors (e.g., transportation, commercial), industries (e.g., forestry, pulp and paper manufacturing) and specific end uses (e.g., space heating, refrigeration). The basic formulation used here, a Laspeyres factorization method, has been used extensively in international comparisons of energy use.

2 The Factorization Method

Although the ratio of energy to gross domestic product (GDP) provides a broad indicator of overall energy intensity in the economy, many researchers have pointed out that changes to this indicator result from both structural changes in the economy as well as technical efficiency improvements. Thus, for example, the industrial sector would contribute to a lower energy/GDP ratio if energy use declined in relation to GDP, even if industrial energy intensity remained unchanged.

[1] B. Jenness, M. Haney and A. Storey, *Energy Efficiency Indicators: Conceptual Framework and Data Sources,* Prepared by Informetrica Limited for Natural Resources Canada, March 31, 1995.

The factorization method involves a basic identity for total energy use that includes three variables: total sector activity, outlet activity, and outlet energy intensity. The exact formulation of the factorization model is as follows:

$$E_{it} = A_{it} \sum_{j} S_{ijt} I_{ijt} \tag{1}$$

where, E_{it} is the total energy use in sector i at time t,

A_{it} is the aggregate activity level in sector i at time t,

S_{ijt} is the level of specific activity j per unit of aggregate activity, and

I_{ijt} is the energy intensity of specific activity j at time t.

In application, the influence of the different component variables in the factorization method can be isolated by maintaining all variables, except the one of interest, constant at their base-year levels, and computing the percentage change in total energy use.

The activity effect is computed as

$$\%\Delta E_{Ai} = \frac{A_{it} \sum_{j=1}^{n} S_{ij0} I_{ij0} - E_{i0}}{E_{i0}} \tag{2}$$

The structure effect is computed as

$$\%\Delta E_{Si} = \frac{A_{i0} \sum_{j=1}^{n} S_{ijt} I_{ij0} - E_{i0}}{E_{i0}} \tag{3}$$

The intensity effect is computed as

$$\%\Delta E_{Ii} = \frac{A_{i0} \sum_{j=1}^{n} S_{ij0} I_{ijt} - E_{i0}}{E_{i0}} \tag{4}$$

To derive true index measures for these effects, it is necessary to include total energy use for sector i at time t in the numerator of each percentage change formula. This simple transformation results in a Laspeyres formulation for each of the components. These three indexes may be used together to assess the contribution of different pure effects (i.e., activity, structure and intensity) to changes in total energy use over time.

The formulation of the index does give rise to two interaction terms which reflect the interactions among the pure effects. The first interaction term, δ, is designed to account for the interactions between the structure and intensity variables which cannot be completely isolated by the Laspeyres index. The second interaction term, ε, is designed to account for the interactions between the activity index and average intensity (energy use per unit of activity).

The interaction term between structure and intensity, δ, is constructed in the following manner:

$$\delta_j = \sum_j \alpha_j \Delta S_{jt} \Delta I_{jt} \tag{5}$$

where

$$\alpha_j = \frac{S_{j0} I_{j0}}{\sum_j S_{j0} I_{j0}} \tag{6}$$

This interaction term can be thought of as a weighted average of the product of the changes in the intensity and structure variables. It is a weighted average because the weights, α_j, are not necessarily equal and sum to unity over all the subsectors j. It is intuitively appealing to note that the interaction term, δ, will be zero if either the structure or intensity variables, or both, do not change from the base year. More generally, the size of δ is proportional to the magnitude of the change, positive or negative, in the structure and intensity variables.

The interaction term between activity and average intensity, ε, is constructed in the following manner:

$$\varepsilon_t = \Delta A_t \{\Delta S_t + \Delta I_t + \delta_t\} \tag{7}$$

Note that this interaction term, ε, is proportional to the magnitude of the change in the activity index. Changes in the δ term or the structure and intensity indexes can have offsetting effects in the computation of ε.[2] For instance, if the sum of the terms in the brackets of equation (7) is zero then ε will also be zero, even if none of the elements that ε is comprised of are zero. There is no intuitive explanation of what ε represents. The best explanation of what ε represents is that it illustrates that part of the movement in the energy index which can not be isolated into one of the pure effects or an interaction between solely the intensity and structure variables. Given this interpretation, it is very important to realize that the ε term is not a residual term; ε is defined independently from any "total energy" index.

[2] The level form of n_t is equivalent to its change from the base period, Δn_t, because it is equal to zero in the base period.

Both interaction effects tend to be small, relative to the pure effects, since they are second order terms. However, when base-year to end-year changes are large, as may be the case when the base year and the end year are far apart, these interaction terms can become significant.

The three pure effect indexes and the two interaction effects completely exhaust all movements in total energy. The sum of the changes of all five indexes multiplied by the base period energy use is equal to the total change in energy use. This identity is used in Section 4 of this appendix to construct a decomposition of energy use for the whole economy and is mathematically presented there as equation (9).

Total secondary energy consumed in the economy is the sum of the secondary energy consumed by each of the end-use sectors, as defined by Natural Resources Canada (see Appendix C):

1) industrial
2) transportation
3) residential
4) commercial (including public administration)
5) agriculture

The factorization methodology provides a basis for distinguishing between activity, structure and intensity factors, but the activity measure appropriate for any particular sector may not be applicable to another. The following activity measures are used for each sector:

Industrial – GDP originating from the sector
Transportation – passenger-kilometres and freight tonne-kilometres
Residential – number of households
Commercial (including public administration) – floor space.

3 Decomposition Applied to End-Use Sectors

3.1 Industrial Sector

The industrial decomposition is based on energy consumption per unit of industrial output (GDP) for 10 subaggregates in the mining (2), construction (1), forestry (1), and manufacturing (6) subsectors.

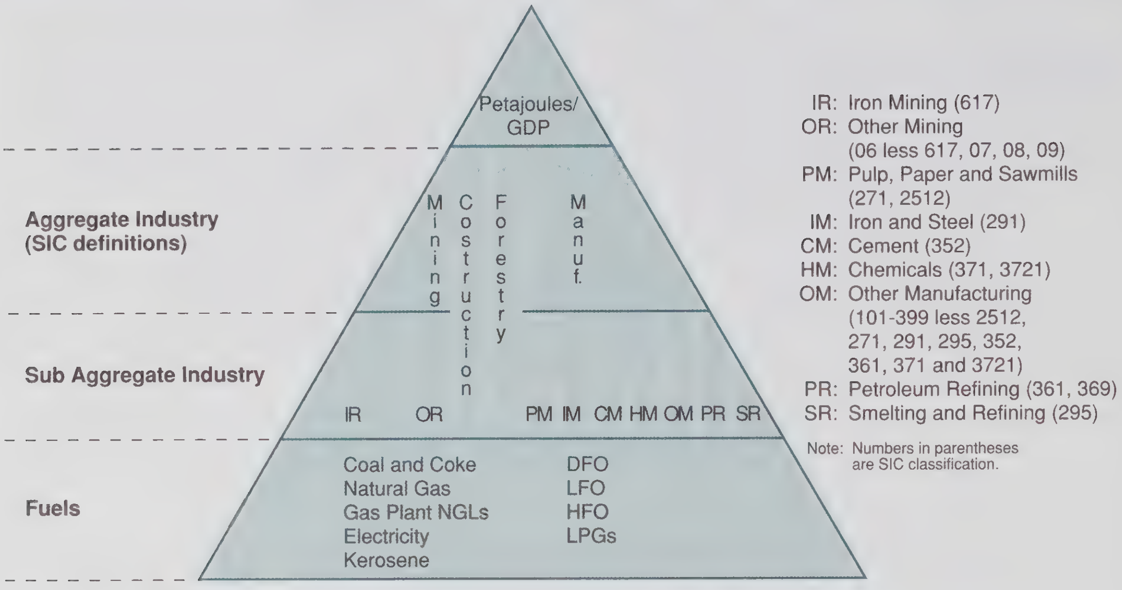
Secondary end-use energy information is produced by Natural Resources Canada for use in their industrial sector energy end-use models. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for hog fuel and pulping liquor consumption, producer's consumption of refined petroleum products, chemical industry non-energy use feedstock demand, and natural gas and coal consumption used as fuel for bitumen production.[3]

Industrial output data for the 10 subsectors are aggregations of GDP by industry (at 1986 prices) data produced by Statistics Canada, published in *Gross Domestic Product by Industry* (15-001). Statistics Canada uses a Standard Industrial Classification system to identify industries; the combinations used in this analysis are identified on the industrial sector indicator pyramid. It should be noted that industry GDP disaggregated by fuel type is not available from Statistics Canada. Instead, estimates were constructed using shares of output energy demand.

As shown on the indicator pyramid (Figure B.1), the factorization of energy use for the industrial sector involves four levels. Level 1 (at the bottom) defines the sectoral influences at the most detailed level by fuel type. Levels 2 and 3 capture the influence of shifting industrial composition. Aggregating over the products of these factors yields the fourth level, the change in aggregate industrial secondary end-use attributable to each of the three components (activity, structure and intensity) in petajoules per unit of output.

[3] The adjustments to Statistics Canada data are documented in Appendix C.

Figure B.1
Industrial Sector Indicator Pyramid



3.2 Transportation Sector

The structure for analyzing transportation is based on a division of transportation activity into two parts: passenger and freight.

3.2.1 Passenger Transport

The passenger transport decomposition is based on energy consumption per passenger-kilometre for seven modal subaggregates in the road (3), bus (2), rail (1), and air (1) subsectors.

Secondary end-use energy information is produced by Natural Resources Canada for use in their transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and some historical revisions.[4] Bus end-use energy demand was derived using data reported in Statistics Canada's *Passenger Bus* and *Urban Transit Statistics* (53-215) and was netted off Natural Resources Canada's reported energy use figures for medium/heavy and extra heavy trucks.

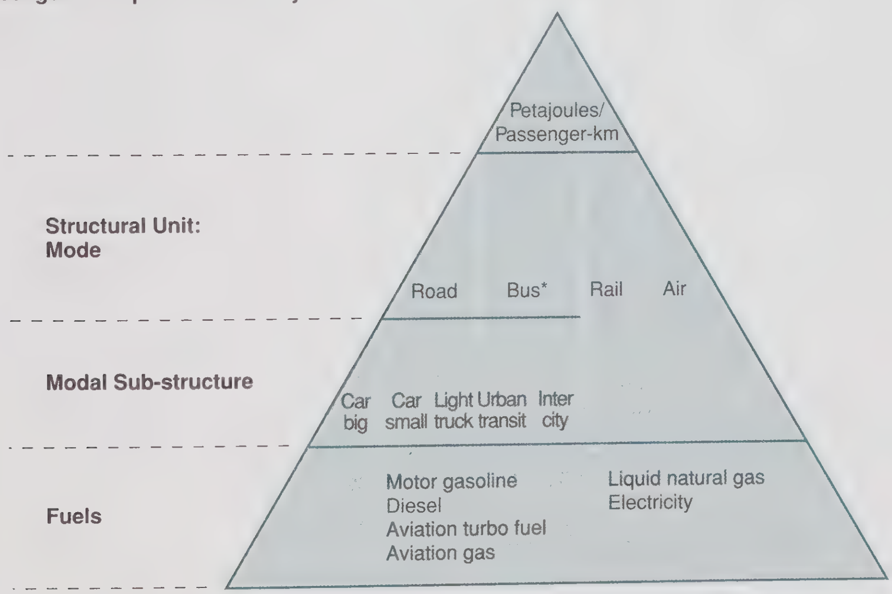
[4] The adjustments to Statistics Canada data are documented in Appendix C.

Passenger-kilometre data are drawn from a number of sources:

- **Road Data** are based on the change in the average population per vehicle benchmarked in 1990 to the average number of passengers per car reported in the *Royal Commission on Passenger Transportation,* Volume 2, multiplied by the distance cars travel. The same average number of passengers per car benchmark is used for both large and small cars. Trucks are defined as light trucks excluding those used for commercial purposes.
- **Bus Data** are approximated as the product of the total number of passengers times the total distance buses travel. Both data series are drawn from Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215). Actual passenger-kilometres are assumed to be a constant multiple of this proxy. As this is not a true passenger-kilometre figure, bus activity, structure and intensity measures were not incorporated into the top level factorization for this sector.
- **Rail Data** are reported in Statistics Canada's *Rail in Canada* (52-216).
- **Air Data** are drawn from Natural Resources Canada's database, which are based on Statistics Canada's airline traffic statistics.

As shown on the indicator pyramid (Figure B.2), the factorization of energy use for the passenger transport sector involves four levels. In this instance, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.2
Passenger Transport Indicator Pyramid



* Not decomposed in aggregate factorization

3.2.2 Freight Transport

The freight transport decomposition is based on energy consumption per freight tonne-kilometre for five modal subaggregates in the truck (3), rail (1) and marine (1) subsectors.

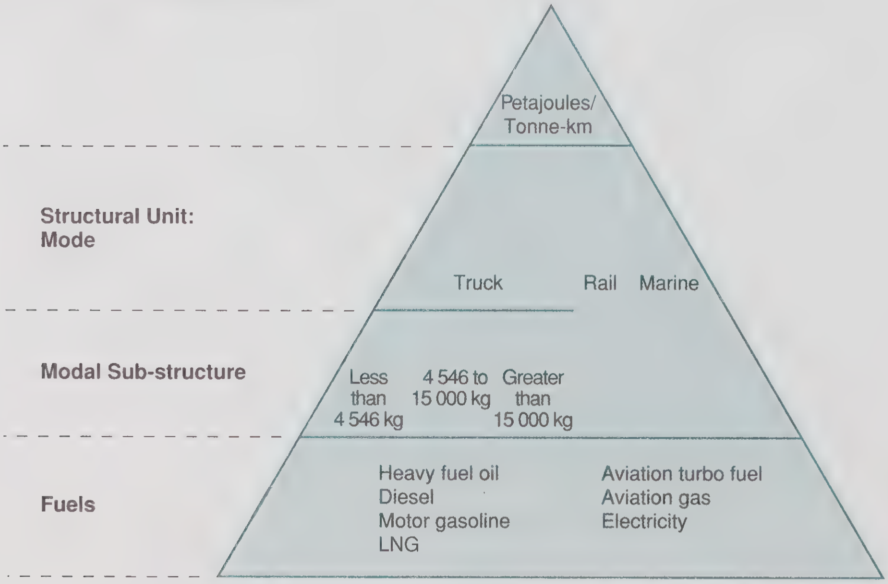
Secondary end-use energy information is produced by Natural Resources Canada for use in their transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and some historical revisions.[5] End-use energy demand by medium/heavy and extra heavy trucks was scaled down by the amounts reported for bus passenger transport.

Freight tonne-kilometre data are drawn from a number of sources:

- **Truck Data** were drawn from Statistics Canada's *Trucking in Canada* (53-222). Light trucks are defined as excluding those used for personal use. Tonne-kilometres were attributed by fuel type based on input fuel consumption.
- **Rail Data** were drawn from Statistics Canada's *Rail in Canada* (52-216).
- **Marine Data** were drawn from Natural Resources Canada's transportation sector end-use model which are based on information found in Statistics Canada's *Shipping in Canada* (54-205).

As shown on the indicator pyramid (Figure B.3), the factorization of energy use for the freight transport sector involves four levels. Once again, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.3
Freight Transport Indicator Pyramid



5 The adjustments to Statistics Canada data are documented in Appendix C.

3.3 Residential Sector

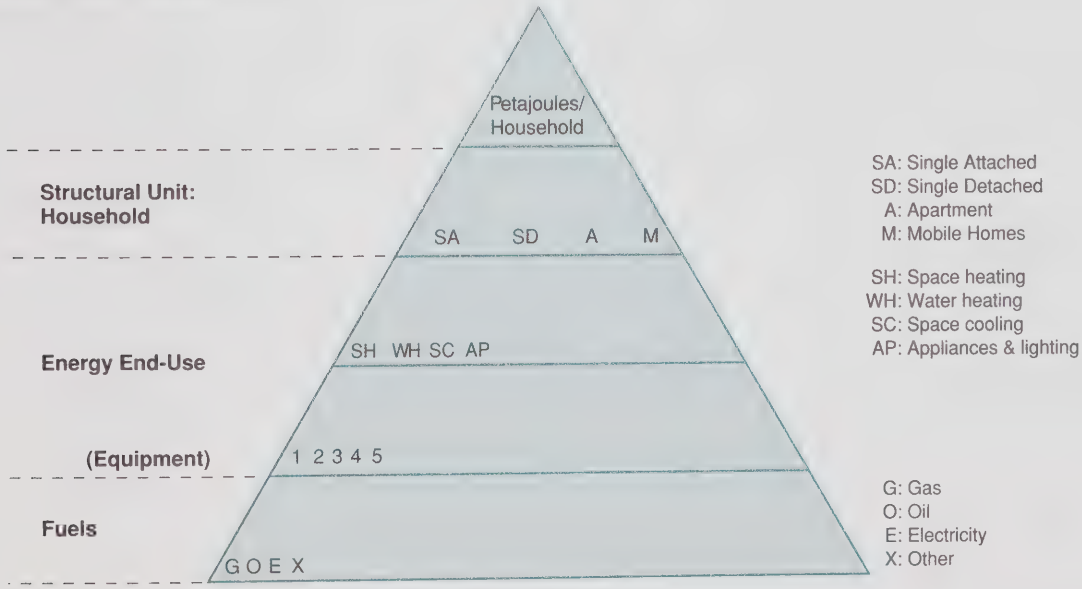
The residential decomposition is based on energy consumption per household. Four structural household units, defined along housing-type lines, are examined.

Secondary end-use energy information is produced by Natural Resources Canada for use in their residential sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for wood use; apartment fuel use is reallocated from the commercial sector in Quebec, Ontario, Alberta and British Columbia and some historical revisions.[6]

Household data are also produced by Natural Resources Canada and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division, and Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.4), the factorization of energy use for the residential sector involves five levels. For this sector, Levels 2 and 3 measure the impact of shifting equipment choice. Level 4 captures the influence of household-type mix.

Figure B.4
Residential Sector Indicator Pyramid



Equipment examples include:
For space heating – high-efficiency furnace, heat pumps, stoves, etc.
For space cooling – room air conditioner, central air conditioner, etc.
For appliances – refrigerator, freezer, stove, washer, dryer, etc.

6 The adjustments to Statistics Canada data are documented in Appendix C.

3.4 Commercial Sector

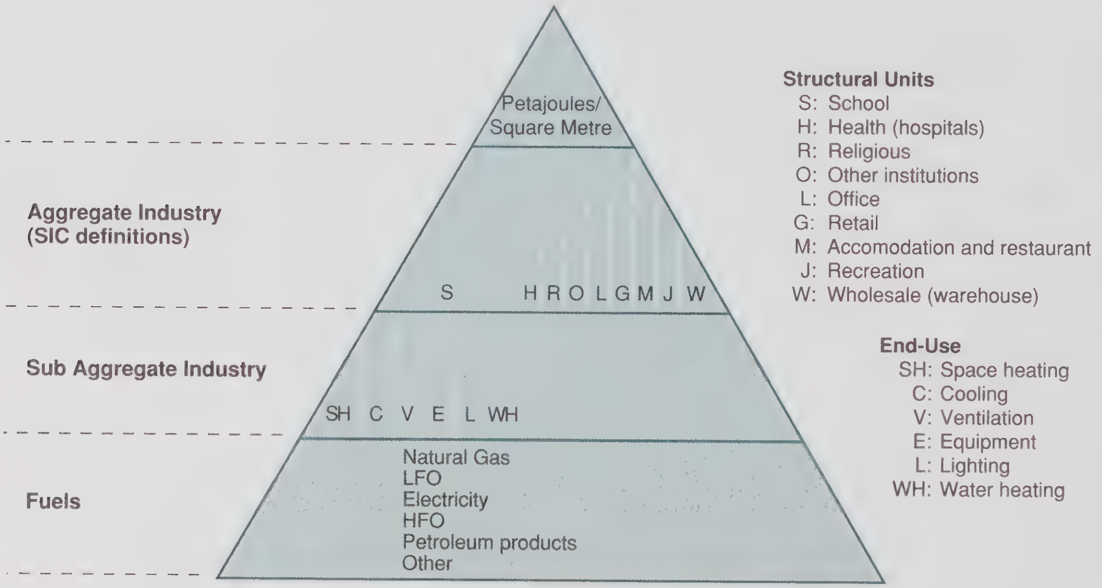
The commercial decomposition is based on energy consumption per square metre of floor space for nine building types.

Secondary end-use energy information is produced by Natural Resources Canada for use in their commercial sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for apartment fuel use reallocated to the residential sector in Quebec, Ontario, Alberta and British Columbia; diesel fuel oil use reallocated to the transportation sector; and some historical revisions.[7]

Floor space data are produced by Informetrica Limited for Natural Resources Canada and are based on investment and capital stock data produced by Statistics Canada, Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.5), the factorization of energy use for the commercial sector involves four levels. For this sector, Level 2 captures equipment mix effects, while Level 3 captures the influence of building types.

Figure B.5
Commercial Sector Indicator Pyramid



[7] The adjustments to Statistics Canada data are documented in Appendix C.

3.5 Adjustments for Weather

Weather and weather-adjusted intensity indexes were constructed for the commercial and residential sector factorizations. In the commercial factorization, the space heating and space cooling components were adjusted; in the residential factorization, only space heating was adjusted. Weather adjustments were made at each level of the factorization: the end-use level, the structural level, and the aggregate level.

At the end-use and structural levels, the weather index was computed directly and the weather-adjusted intensity index was implicitly computed from the former. The weather index was computed as the degree day elasticity variable (either heating or cooling days), in the current year, divided by itself in the base year. The weather-adjusted intensity index was then constructed by dividing the original intensity index by the weather index.

For the aggregate level factorization, the weather-adjusted intensity index was directly computed and the weather index was implicitly computed from the former. This approach was used so that the weather index, taking into account both degree heating and cooling days, would be a measure of weather severity. For instance, the weather index will be greater than unity if the winters were colder and the summers were hotter in the current year as compared to the base year. The weather-adjusted intensity index was computed in the same manner as the unadjusted index except that the individual intensity variables were slightly altered. The energy-use levels, used to construct each of the intensity variables, were divided by the associated degree days elasticity variable. Thus, in hot summers the energy use for commercial space cooling would be scaled down by the inverse of the cooling degree days' elasticity variable. The weather index was implicitly constructed from the two intensity variables; it is equal to the ratio of the unadjusted to the weather-adjusted intensity indexes.

This technique of accounting for weather results in an interaction term between the weather and weather-adjusted intensity indexes. The interaction is limited to that between the two indexes and does not affect the other indexes. This interaction effect, λ, is simply the product of the change in each of the weather and weather-adjusted intensity indexes. This interaction term will be discussed in more depth in the following section.

4 Decomposition Applied to the Total Economy

To construct a total economy factorization index, a common activity variable must be employed for all sectors. At first glance, the obvious choice would be GDP, but the sector definitions do not suggest an obvious segmentation of total GDP. This occurs because GDP can not be attributed to the personal sector. Therefore, at the total economy level, activity, structure and intensity can not be disentangled in the usual manner. Instead, the aggregate energy-use relationship can be expressed as follows:

$$E_t = E_{1t} + E_{2t} + E_{3t} + E_{4t} + E_{5t} \qquad (8)$$

Equation (8) simply states that energy use for the whole economy is the sum of energy use over an exhaustive disaggregation of the economy. The chosen disaggregation follows that of the previous section. Using the factorization indexes that were described in the previous section, activity, structure, intensity and interaction effects can be implicitly computed for the total economy as the sum, over all sectors, of the changes in the level of energy use that would have resulted, given that all other factors remained constant at base year values. The following identity is used to construct, on a sector-by-sector basis, the level changes in energy resulting from activity, structure, intensity and interaction effects:

$$\Delta E_t = E_0 \{\Delta A_t + \Delta S_t + \Delta I_t + \Delta\delta_t + \Delta\varepsilon_t\} \quad (9)$$

Again, δ_t and ε_t are the interaction terms; the former captures the interaction between intensity and structure, and the latter captures the interaction between activity and average intensity.

Using equation (9), one can compute the change in energy use from base-year levels due to each one of the separate effects. This level-form decomposition was performed on all the sectors defined in the previous section. Then the change in energy resulting from changes in activity was summed over all sectors to yield the total economy activity effect in level form. The same computation was done for each index element to yield the total economy activity, structure, intensity and interaction effects. The sum of these total economy effects is identically equal to the change in total economy energy use.

As noted in the previous section, for the residential and commercial sectors, a weather-adjusted factorization was also calculated. Two new indexes were computed, a weather and a weather-adjusted intensity index. These indexes were designed to help explain the changes in the intensity index only. A comprehensive level form breakdown of the intensity index can be accomplished with the weather and weather-adjusted intensity indexes and a new interaction term. The exact formulation of this interaction term, λ, is as follows:

I_t is defined as

$$I_t = \frac{\sum_j S_{jt} I_{jt}}{\sum_j S_{j0} I_{j0}}$$

where

$$I_{jt} = \frac{E_{jt}}{H_{jt}}$$

and I_t' is defined as

$$I_t' = \frac{\sum_j S_{jt} I_{jt}'}{\sum_j S_{j0} I_{j0}'}$$

where

$$I_{jt}' = \frac{E_{jt}'}{H_{jt}} = \frac{E_{jt}}{H_{jt}} \times \frac{1}{DD_{jt}}$$

E_{jt} is the energy use associated with some specific activity, H_{jt}, at time t, and DD_{jt}, is a degree day elasticity associated with the specific activity H_{jt}. Now we define the weather variable, W_t, as follows:

$$W_t = \frac{I_t}{I_t'}$$

The change in energy use that was previously associated only with intensity changes will be divided between a weather-adjusted intensity index and weather index in the following manner:

$$(E_t - E_0)_{Intensity} = E_0 \left[\frac{I_t}{I_0} - 1 \right]$$

$$= E_0 \left[\frac{W_t\, I_t'}{W_0\, I_0'} - 1 \right]$$

Therefore,

$$E_t = E_0 + E_0 \left[\frac{W_t\, I_t'}{W_0\, I_0'} - 1 \right]$$

and

$$E_t = E_0 \left[\frac{I_t'}{I_0'} \right] + E_0 \left[\frac{W_t\, I_t'}{W_0\, I_0'} - \frac{I_t'}{I_0'} \right]$$

By subtracting E_0, from both sides of the last equation and some simple manipulations, we get the following:

$$(E_t - E_0)_{Intensity} = E_0 \left\{ \left[\frac{I_t'}{I_0'} - 1 \right] + \frac{I_t'}{I_0'} \left[\frac{W_t}{W_0} - 1 \right] \right\}$$

$$\lambda = E_0 \left\{ \left[\frac{I_t'}{I_0'} - 1 \right] + \left[\frac{W_t}{W_0} - 1 \right] + \left[\frac{I_t'}{I_0'} - 1 \right] \left[\frac{W_t}{W_0} - 1 \right] \right\}$$

Therefore, the change in energy use originally associated only with intensity is now attributed to weather-adjusted intensity, weather and an interaction term. Each of these effects can be seen, in order, in the brackets of the last equation. The new interaction term, λ, is merely the product of the weather and weather-adjusted intensity indexes. The formation is identical to how the level changes were constructed for the original factorization indexes.

As a result of this technique, we can aggregate changes in energy use at the sector level to arrive at a decomposition of total energy change into pure and interaction effects. That is, we can “fill in” the following table:

TOTAL ECONOMY CHART

		Pure Effects				Interaction Effects		
Sector	Change in Energy	Activity	Structure	Intensity*	Weather	Structure Intensity	Activity/ Avg. Intensity	Weather/ Intensity
Commercial								
Industrial					n.a.			n.a.
Residential								
Passenger Transportation					n.a.			n.a.
Freight Transportation					n.a.			n.a.
Other	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total Economy								

* For the Commercial and Residential sectors this could be intensity or weather-adjusted intensity.

Note: the “Other” component was not factorized. It includes agriculture energy use, commercial/institutional air sector energy use and marine sector energy use.

The **Change in Energy** column is simply the difference between end-year and base-year energy use per sector. The **Total Economy** row is defined as the column total. It should also be noted that the sum of all pure and interaction effects will be equal to the change in energy for each sector as well as for the total economy.

Reconciliation of Data on Energy Use Found in this Report with Statistics Canada's *Quarterly Report on Energy Supply and Demand Data*

1 Introduction

The bulk of the energy-use data presented in this report is taken from Statistics Canada's *Quarterly Report on Energy Supply and Demand (QRESD)*. However, for the purpose of the analysis undertaken in this study, some sectoral reallocations of the original Statistics Canada data was required. These adjustments are illustrated in Table C.1 on page 85.

While our preference would have been to use *QRESD* data as is, some of the sectoral allocations in the *QRESD* were judged not to be adequate for energy end-use analysis. For example, Statistics Canada's definition of the commercial sector includes the use of aviation fuel by the public sector. NRCan's end-use analytical framework for the commercial sector estimates building energy use. Using unmodified *QRESD* sector definitions would have led to the inclusion of public-used aviation fuels in the commercial sector and their allocation to one of the building types defined in the Natural Resources Canada's commercial end-use database. We did not find this approach acceptable for the type of analysis done in this report.

The following describes the modifications that were done to *QRESD* sector definitions in each end-use sector for the purpose of this report.

2 Residential Sector

Two modifications were made to the *QRESD* definition of the residential sector: the addition of fuel wood use and the reallocation of apartment energy use from the commercial sector.

The inclusion of fuel wood use is a net addition to residential energy demand as reported in the *QRESD*. Residential fuel wood use is estimated using Natural Resources Canada's Residential End-use Model.

The reallocation of apartment energy demand from the commercial to the residential sector is required because in some provinces utilities categorize apartments as commercial accounts. Since utilities report these data to Statistics Canada according to the account category, some apartment energy demand is misclassified in the commercial sector. This reallocation is done with data provided by the British Columbia Gas, Transalta, Ontario Hydro and Hydro-Québec.

3 Agricultural Sector

No modification.

4 Commercial Sector

Two modifications were made to the *QRESD* definition of the commercial sector: the reallocation of apartment energy use to the residential sector and the reallocation of commercial motive fuels to the transportation sector.

The reallocation of apartment energy demand from commercial to residential is the mirror adjustment to that described above for the residential sector.

The reallocation of commercial motive fuels is done in order to include only stationary energy use in the commercial sector. All of the data required for this reallocation are found in the *QRESD* and described in Table C.1.

5 Industrial Sector

Two types of modifications were done to the *QRESD* definition of the industrial sectors: two reallocations of energy demand to other sectors and two net additions of energy demand.

The reallocations relate to producer consumption by the refining industry and to fuel use by the chemicals industry.

Statistics Canada classifies the use of non-purchased petroleum products by the petroleum refining industry as producer consumption. In this report, this energy use has been reallocated to the industrial sector/petroleum refining industry, as it is an end-use consumption. All of the data required for this reallocation are found in the *QRESD* and described in Table C.1.

Statistics Canada allocates some of the chemical industry's fuel use to the non-energy sector. This energy is reallocated in this report to the industrial sector/chemical industry using data provided by the Alberta ERCB.

Table C.1
Reconciliation of Data on Energy Use Found in this Report with
Statistics Canada *Quarterly Report on Energy Supply and Demand Data* - 1994

SECTOR	QRESD Data	Fuel Wood	Apartment Energy Use	Commercial & Public Admin. Aviation Fuel	Commercial & Public Admin. Motor Gasoline	Commercial & Public Admin. Diesel	Pipeline Fuels	Fuel for Bitumen Production	Wood Waste & Pulping Liquor	Producer Consumption by Refining Industry	Chemical Ind. Fuel/Feedstock Adjustment	Producer Consumption of Natural Gas & Crude Oil	Energy Efficiency Trends Data
Residential	1 277	85.1	30.1										1 392
Agriculture	195												195
Commercial	1 112		(30.1)	(28.3)	(50.5)	(67.1)							936
Transportation	2 027			28.3	50.5	67.1	(223.5)						1 949
Industrial	2 086							66.5	436.1	234.9	17.6		2 841
Final Demand	6 697	85.1	0.0	0.0	0.0	0.0	(223.5)	66.5	436.1	234.9	17.6	0.0	7 314
Non energy	745										(17.6)		727
Producer Consumption	976						223.5			(234.9)		(589.8)	375
Net supply	8 418	85.1	0.0	0.0	0.0	0.0	0.0	66.5	436.1	0.0	0.0	(589.8)	8 416
Conversion	1 661												1 661
Total primary	10 079	85.1	0.0	0.0	0.0	0.0	0.0	66.5	436.1	0.0	0.0	(589.8)	10 077

Notes on sources of data for calculation of energy use by sector:

RESIDENTIAL
Base data taken from QRESD (in 1994 issue of QRESD Table 1B line 43) plus fuel wood use (estimated from NRCan's Residential End-Use Model) plus apartment energy use classified in commercial accounts by some utilities (estimated using utilities data).

AGRICULTURE
Base data taken from QRESD (in 1994 issue of QRESD Table 1B line 42).

COMMERCIAL
Base data taken from QRESD (in 1994 issue of QRESD Table 1B line 44 plus line 45) less apartment energy use classified in commercial accounts by some utilities (estimated using utilities data) less commercial and public administration motor gasoline (in 1994 issue of QRESD Table 1C, diesel column, line 44 plus line 45) less commercial and public administration aviation gasoline (in 1994 issue of QRESD Table 1C, aviation gasoline column, line 44 plus line 45) less commercial and public administration aviation turbo fuel (in 1994 issue of QRESD Table 1C, aviation turbo fuel column, line 44 plus line 45).

TRANSPORTATION
Base data taken from QRESD (in 1994 issue of QRESD Table 1B line 41) less pipeline fuels (in 1994 issue of QRESD Table 1B, natural gas plus electricity plus petroleum products columns, line 38) commercial and public administration diesel (in 1994 issue of QRESD Table 1C, motor gasoline column, line 44 plus line 45) plus commercial and public administration diesel (in 1994 issue of QRESD Table 1C, diesel column, line 44 plus line 45) plus commercial and public administration aviation gasoline (in 1994 issue of QRESD Table 1C, aviation gasoline column, line 44 plus line 45) plus commercial and public administration aviation turbo fuel (in 1994 issue of QRESD Table 1C, aviation turbo fuel column, line 44 plus line 45).

INDUSTRIAL
Base data taken from QRESD Table 1B line 30) plus fuel for bitumen production (estimate provided by Alberta ERCB) plus hog fuel and pulping liquor (in 1994 of QRESD Table 19) plus producer consumption by refinery industry of still gas, diesel, heavy fuel oil, kerosene, petroleum coke and refinery LPG's (in 1994 issue of QRESD Table 1D, still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG's columns, line 15), plus chemical industry feedstock adjustment (estimate provide by Alberta ERCB).

* Electricity conversion rates: Hydro converted at rate of 3.6 megajoules per kilowatt hour; nuclear converted at rate of 11.564 megajoules per kilowatt hour.

The net additions to energy use relate to solid wood waste, spent pulping liquor and fuel for bitumen production.

Data on consumption of solid wood waste and spent pulping liquor are included in a supplementary table in the *QRESD* but not in the *QRESD*'s energy supply/demand balance. For the purpose of this report, the energy demand of the industrial sector is defined to include solid wood waste and spent pulping liquor consumption. The location of these data in the *QRESD* is described in Table C.1.

Data on fuel for bitumen production are added to *QRESD* industrial sector energy use. These data are provided by the Alberta ERCB.

6 Transportation Sector

Two modifications were made to the *QRESD* definition of the transportation sector: the reallocation of commercial motive fuels from the commercial sector and the reallocation of pipeline fuel use to producer consumption.

The reallocation of commercial motive fuels from the commercial sector to the transportation sector is the mirror adjustment to that described above for the commercial sector.

The reallocation of pipeline fuel use to producer consumption is done in order to include only vehicle energy use in the transportation sector. Since pipeline fuel is used in the distribution of energy to end-use markets, we have reallocated it to producer consumption and do not consider it end-use consumption. All of the data required for this reallocation are found in the *QRESD* and described in Table C.1.

Glossary

The Glossary is divided into five sections: General, Residential Sector, Commercial Sector, Industrial Sector, and Transportation Sector. The General section includes general terminology as well as terminology common to more than one sector.

General

Activity: Term used to characterize major drivers of energy use in a sector (e.g., number of households in the residential sector).

Building Envelope: The materials and surfaces in the building shell, including walls, ceilings, roof, basement walls, windows and doors.

Canada's National Action Program on Climate Change (NAPCC): Sets strategic directions in pursuit of Canada's commitment to work towards stabilizing greenhouse gas emissions at 1990 levels by the year 2000 and provides guidance for actions beyond the year 2000. NAPCC pursues sectoral and broad-based opportunities through the development of appropriate actions and measures by private and public jurisdictions, reviews progress, and makes adjustments as required.

Carbon Dioxide: A compound of carbon and oxygen formed whenever carbon is burned. Chemical formula: CO_2. Carbon dioxide is a colourless gas that absorbs infrared radiation mostly at wavelengths between 12 and 18 microns; it behaves as a one-way filter allowing incoming visible light to pass through in one direction while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus, it acts as a greenhouse and has the potential to increase the surface temperature of the earth. Energy use accounts for 98 per cent of CO_2 emissions (see **Greenhouse Effect**).

Climate Change: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is, in addition to natural climate variability, observed over comparable time periods.

Compressor: A compressor is used in refrigeration and cooling systems to compress vaporized refrigerant.

Cooling Degree Days: A measure of how hot a location was over a period of time relative to a base temperature. In this report, the base temperature is 21°C; the period of time is one year. The cooling degree days for a single day is the difference between that day's average temperature and 21°C, if the daily average exceeds the base temperature, and it is zero, if the daily average is less than or equal to the base temperature.

The cooling degree days for a longer period of time is the sum of the daily cooling degree days from the days in the period.

End Use: Any specific activity that requires energy, e.g., refrigeration, space heating, water heating, manufacturing process, feedstocks.

Energy Efficiency Indicators: Indicators of how efficiently energy is used.

Energy Intensity: The amount of energy use per unit of activity (examples of activity measures in this report are households, floor space, passenger-kilometres, tonne-kilometres, and constant dollar value of Gross Domestic Product for services).

Energy Source: Any substance that supplies heat or power, e.g., petroleum, natural gas, coal, renewable energy, and electricity, including the use of a fuel as a non-energy feedstock.

Factorization Method: A method used to disentangle changes in the total energy used in a sector, over a certain period of time, into changes in the overall demand for that sector's output, changes in the structural composition of the sector, and changes in the energy intensity of the individual sub-sectors contributing to the sector's output. The factorization method used in this report is the Laspeyres index.

Fossil Fuel: Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

Framework Convention on Climate Change (FCCC): United Nations convention to address climate change (see **Climate Change**), signed by more than 150 countries at the United Nations Conference on Environment and Development, in Rio de Janeiro, in June 1992. Canada became the eighth country to ratify the Convention, which entered into force on March 21, 1994, thereby committing to work towards stabilizing greenhouse gas emissions at 1990 levels by the year 2000.

Gigajoule: One gigajoule equals 1×10^9 joules. A joule is the international unit of energy – the energy produced by a power of one watt flowing for one second. There are 3.6 million joules in one kilowatt-hour (see **Kilowatt-hour**).

Global Warming: See **Greenhouse Effect**.

Greenhouse Effect: An effect whereby infrared radiation (i.e., heat) emitted by a body that has absorbed energy from the sun, is trapped in a space enclosed by glass or other material that is largely opaque to infrared radiation (hence preventing radiant heat losses) but transparent to other incoming solar radiation. The term "greenhouse effect" is most often used to suggest an increase in earth's temperature well above what it otherwise would be. For clarity, global warming is sometimes used. (See **Carbon Dioxide and Greenhouse Gas.**)

Greenhouse Gas: A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4, CFCs and NO_x. By far the most abundant greenhouse gas is CO_2, accounting for 70 per cent of the greenhouse effect (see **Greenhouse Effect** and **Carbon Dioxide**).

Gross Domestic Product (GDP): The total value of goods and services produced by the Nation's economy before deduction of depreciation charges and other allowances for capital consumption, labour and property located in Canada. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade. GDP figures are reported in real 1986 dollars.

Heating Degree Days: A measure of how cold a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The heating degree days for a single day is the difference between that day's average temperature and 18°C, if the daily average is below the base temperature, and it is zero, if the daily average exceeds or equals the base temperature. The heating degree days for a longer period is the sum of daily heating degree days for days in that period.

Hydroelectric Generation: Electricity produced by an electric generator driven by a hydraulic turbine.

Interaction Effect: In the factorization method, this is a weighted average of the change in intensity and structure variables.

Kilowatt-hour (kWh): The commercial unit of electric energy equivalent to 1000 watt hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt light bulbs burning for an hour. One kilowatt-hour is equal to 3.6 million joules (see **Watt**).

Megajoule: One megajoule equals 1 x 10^6 joules (see **Gigajoule**).

Megawatt-hour (MWh): One megawatt-hour equals 1 x 10^6 watt hours (see **Kilowatt-hour**).

Motive Power: Power provided by electric motors for driving fans, pumps, elevators or other type of equipment.

Penetration Rate: The rate at which a technology infiltrates the stock of buildings (e.g., number of refrigerators per household at a specified time).

Per Capita: Per person.

Petajoule: One petajoule equals 1 x 10^{15} joules (see **Gigajoule**).

Petroleum: A naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Primary Energy Use: Represents the total requirements for all uses of energy, including energy used by the final consumer (see **Secondary Energy Use**), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g., coal to electricity), and energy used by suppliers in providing energy to the market (e.g., pipeline fuel).

Production of Electricity: The amount of electric energy expressed in kilowatt hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g., peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels, and environment constraints.

Real Disposable Income per Household: Money, in constant dollars, available to individuals per household for spending and saving after taxes and social insurance premiums, such as unemployment insurance and Canada Pension Plan premiums, have been deducted. Personal disposable income is the principal source of savings and spending in the economy.

Retrofit: Improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Secondary Energy Use: Energy used by final consumers for residential, agriculture, commercial, industrial and transportation purposes.

Sector: The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g., residential, agriculture, commercial, industrial, and transportation).

Space Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air conditioner or heat pump) or by circulating chilled water through a central cooling or district cooling system.

Space Heating: The use of mechanical equipment to heat all or part of a building. Includes both the principal space heating and supplementary space heating equipment.

Structural Change: As it affects energy efficiency, structural change is a change in the shares of activity accounted for by the energy-consuming sub-sectors within a sector. An example of structural change is change in product or industry mix in the industrial sector.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water heating equipment for bathing, cleaning and other non-cooking applications.

Watt (W): A measure of energy, for example a 40-watt light bulb uses 40 watts of electricity (see **Kilowatt-hour**).

Weather-adjusted Energy Intensity: A measurement of energy intensity which excludes the impact of weather.

Residential Sector

Annual Fuel Utilization Efficiency (AFUE): This is an energy rating (stated as a percentage, such as 90 per cent) that indicates how efficiently a new furnace or boiler will heat a home. The higher the number, the more efficient the heating equipment.

Apartment: This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes, i.e., where the division between dwelling units is horizontal; suites in structurally converted houses; living quarters located above or in the rear of stores, restaurants, garages or other business premises; janitors' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions.

Appliances: Energy-consuming equipment used in the home for purposes other than the conditioning of air or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, colour televisions, water bed heaters, swimming pool heaters, hot tubs, and spas.

Dwelling: A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside. A private dwelling is where one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

Heated Living Area: The area within a dwelling, which is space heated.

Household: A person or a group of persons occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings. The person or persons occupying a private dwelling form a private household.

Household Size: The number of persons per household.

Mobile Home: A moveable dwelling designed and constructed to be transported (by road) on its own chassis to a site, and placed on a temporary foundation such as blocks, posts or a prepared pad. It should be capable of being moved to a new location.

Resistance Value: Resistance value, or R-value, represents a material's resistance to heat flow. The higher the R-value, the greater the insulating power.

Single Attached Dwelling: Each half of a semi-detached (double) house and each section of a row or terrace is defined as a single attached dwelling. A single dwelling attached to a non-residential structure also belongs in this category.

Single Detached Dwelling: This type of dwelling is commonly called a single house, i.e., a house containing one dwelling unit and completely separated on all sides from any other building or structure.

Commercial Sector

Auxiliary Equipment: See **Electric Plug Load**.

Burner: The part of a gas or oil space heating system which produces the flame and controls the ratio of air to fuel in the combustion mixture.

Computerized Energy Monitoring System: System designed to monitor the environment and the use of energy in a facility. Normally used in conjunction with energy management systems.

Condenser: A component, usually a vessel or arrangement of pipe, that releases heat causing low-pressure gas in the system (refrigerants or steam) to be converted into a liquid.

Electric Plug Load: Unitary equipment powered directly from an electric outlet (e.g., computers, photocopiers, refrigerators and desktop lamps).

Energy Management Control System: System used to manage building energy consumption and conserve energy while maintaining a suitable environment.

Evaporator: Heat exchanger which adds heat to a liquid, changing it to a gaseous state (in cooling systems, it is the component that absorbs heat).

Floor Area (Space): The area enclosed by exterior walls of a building, including parking areas, basements, or other floors below ground level. It is measured in square metres.

Free-cooling Economizers: Automatic control which readjusts outside air to take advantage of the cooling effect which may be available.

Occupancy Rate: The number of occupants per square metre of floor area.

Rare-earth Phosphor Lamps: Fluorescent tubes have a phosphor material coating to convert ultra-violet light into visible light. Over time, phosphor deteriorates and light output decreases. Rare-earth phosphor lamps incorporate several rare-earth phosphors that provide high colour rendition while maintaining a better lighting output over the lamp's lifetime.

Seasonal Efficiency: A measurement of a heating system's performance through all of the on and off cycles of a normal heating season. It can be measured only under laboratory conditions.

T-8 System: Fluorescent lighting system using reduced diameter lamps (T-8 tubes have a diameter of 1 inch compared to 1.5 inches for standard tubes). Lamps of this type use less power to produce the same amount of light as a standard lamp. They require special fixtures and dedicated ballasts.

Thermal Storage: A system capable of providing cooling or heating to buildings by storing heating or cooling energy produced during the night.

Industrial Sector

Aluminum Smelters: Reduction cells that contain cryolite bath needed by the aluminum industry to separate oxygen and aluminum from alumina.

Capacity-utilization Rate: The ratio of industrial production to capacity (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule).

Chemical Pulping: Process that generates intact wood fibres using steam and various chemicals. This pulping process is used for high-quality and high-strength paper.

Clinker: Intermediate product in the cement production. A grey granular material obtained from the burning of a raw material mixture (usually limestone, clay or shale, sand, bauxite and iron ore).

Cogeneration: A process which produces steam heat as well as electricity resulting in an overall improvement in energy conversion efficiency.

Coke: A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke Oven Gas: Complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Continuous Casting: A process that directly casts molten steel in a primary mill into smaller and thinner sections without the need for reheating steel ingots.

Dry Process Cement Production: Cement production process in which raw material grinding takes place in the absence of water, reducing the required heating temperature and time during clinker production.

Electric-arc Technology: Use of electrical arcs in a furnace to efficiently produce very high temperatures for applications such as metal melting and coating and industrial drying.

Ingot Casting: Casting method in which the material takes on the approximate shape of its final use. Reheating and soaking is then required before production of final product.

Integrated Mill: Facility that produces steel products from iron ore rather than from ferrous scrap.

Mechanical Pulping: A pulp and paper industry process where wood, in the form of chips or logs, is converted into fibres by abrasion. Because fibres are broken during this process, mechanical pulp and paper products are of lower quality.

Pulp Digesters: Pulp and paper technology used in chemical pulping processes for the release of lignin which bonds wood fibres.

Pulping Liquor: A substance primarily made up of lignin, other wood constituents, and chemicals which are by-products of the manufacture of chemical pulp. It can be burned in a boiler to produce steam or electricity, through thermal generation.

Rotating Kilns: Long steel cylinders in which extensive heating of raw material takes place for cement production.

Soderberg-type Smelters: Carbon anode production process used in the aluminum industry.

Standard Industrial Classification (SIC): A classification system that categorizes establishments into groups with similar economic activities.

Wet Process Cement Production: Cement production process in which raw materials are combined with water before grinding, resulting in greater heating requirements during clinker production (see **Clinker**).

Wood Wastes: Fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

Transportation Sector

Alternative Fuels: Defined to include all fuels other than conventional fuels (i.e., motor gasoline and diesel) used in road transportation.

Average Fuel (Consumption) Efficiency: The amount of fuel required to operate a vehicle over a specified distance. Measured in litres per 100 kilometres travelled.

Drag: Measure of a vehicle's aerodynamic resistance to forward motion expressed as a function of its frontal area and speed of travel.

Drive-train: The drive train of a vehicle consists of the engine, transmission, differential and the drive shaft.

Electronic Controls: These refer to the computerized control of engine operations to ensure that the catalytic converter is not overwhelmed by the mix of emissions it receives. Controls can affect the size of injector openings or the speed at which the fuel pump operates.

Front-wheel Drive: A vehicle that has its power supplied through the front wheels.

Large Cars: Defined as cars weighing more than 2600 pounds.

Light Vehicles: Defined to include automobiles, motorcycles, and light trucks (see **Light Trucks**).

Light Trucks: Defined as trucks up to 10 000 pounds of gross vehicle weight.

Multi-point Fuel injection: A system that meters the delivery of high-pressure fuel to injectors at the engine intake ports by an electronic control unit that receives sensor information and computes the required rate of fuel flow to maintain optimum air/fuel ratio through the entire range of engine operations.

Overdrive Transmission: A transmission gear which allows vehicles to travel at highway speeds with reduced engine effort. The ratio of engine revolutions to wheel turns is normally less than 1:1 during overdrive.

Passenger-kilometre: The transport of one passenger over a distance of one kilometre.

Passenger-seating Utilization to Capacity Ratio: This refers to the average number of people travelling in a vehicle compared to the average number of seating spaces in the average vehicle.

Rear-wheel Drive: A vehicle that has its power supplied through the rear wheels.

Small Cars: Defined as cars weighing up to 2600 pounds.

Throttle-body Fuel Injection: A system of forced fuel delivery located at the top of the intake manifold where the carburetor used to be located. It injects fuel into the air stream before the valves open.

Tonne-kilometre: The transport of one tonne over a distance of one kilometre.

Energy Efficiency Trends in Canada 1990 to 1995

A Review of Indicators of Energy Use, Energy Efficiency and Emissions

Demand Policy and Analysis Division

Energy Efficiency Branch

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Preface

This report, the second annual review of trends in end-use energy efficiency in Canada, continues the practice of monitoring trends in energy efficiency and their contribution to changes in energy use and greenhouse gas emissions.

The review differs from the April 1996 report, *Energy Efficiency Trends in Canada*, in that it:

- addresses the period from 1990 to 1995;
- explains changes in greenhouse gas emissions for each end-use sector;
- presents a detailed accounting of the sources of changes in energy use at greater levels of detail; and
- includes end-use survey data, which became available since the last report.

Chapter 1 of the report sets the context and the framework for the study and describes the relationship between energy use and carbon dioxide emissions. Chapter 2 reviews the influence of energy efficiency on secondary energy use and greenhouse gas emissions. Chapters 3 through 6 take a detailed look at sector-by-sector trends in energy use and greenhouse gas emissions over the first half of this decade, with particular attention paid to the role of energy efficiency. Chapter 7 presents an analysis of sectoral emission trends. Electricity use is attributed an emission factor reflecting the average mix of fuels to generate electricity.

Appendix A presents the data used to prepare the graphs in the report. The sources of these data are not documented in the main body of the text, and the reader should consult Appendix A for this information.

Appendix B presents the methodology and data sources that underlie the factorization of energy use.

Appendix C and D present reconciliations of the sectoral definitions used in the report with those found in our major source of energy data, Statistics Canada's *Quarterly Report on Energy Supply-Demand,* and in our major source of emissions data, Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990–1995.*

Appendix E defines the technical terms used in the report.

The report was prepared by staff of the Energy End-Use Analysis and Data Development Group, which is managed by Jean-Pierre Moisan. The project leader was Mark Pearson. Major contributors to the report were André Bourbeau, Maryse Courchesne, Michel Francoeur, Tim McIntosh, Louise Métivier, Cristobal Miller, Alain Paquet, Nathalie Trudeau and Brian Warbanski. Nicholas Marty provided overall direction.

The report was prepared using a methodology and database developed by Informetrica Limited for Natural Resources Canada.

A database containing all of the indicators calculated for this report is available on the Internet by searching for *Energy Efficiency Trends in Canada* at **http://eeb-dee.nrcan.gc.ca**

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1 Appendix A presents a set of tables, one for each figure found in the main body of the text. These tables show the data in the figures and document the sources of these data. Tables in Appendix A are not listed here.

Executive Summary

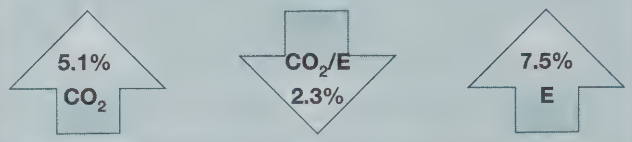
The objective of this report is to explain the contribution of energy efficiency to the evolution of secondary energy use and greenhouse gas emissions in Canada. Promoting greater energy efficiency in all sectors of the economy is an important element of Canada's National Action Program on Climate Change—the federal-provincial strategy to achieve Canada's commitment to work toward returning greenhouse gas emissions to 1990 levels by the year 2000. In this regard, an improved understanding of the relationship between energy efficiency, energy use and greenhouse gas emissions will assist policy-makers in developing more effective responses to the issue of global climate change and sustainable development.

This report reviews trends in four end-use sectors (residential, commercial, industrial and transportation) for the period from 1990 to 1995. The year 1995 was chosen because it is the most recent year for which actual energy use data are available. The year 1990 was chosen because it is the base year of Canada's commitment under the Framework Convention on Climate Change. Future annual energy-efficiency reviews will also use 1990 as the base year.

Secondary Energy Use and Emissions

At the secondary level, energy use is consumed in five sectors: residential, agriculture, commercial, industrial and transportation. Secondary energy use accounts for about 73 percent of the total energy requirements in Canada and about two-thirds of all carbon dioxide emissions.

THE ENERGY/EMISSIONS BAROMETER—SECONDARY



From 1990 to 1995, carbon dioxide emissions (CO_2) resulting from secondary energy use increased by a total of 5.1 percent (or an average rate of 1.0 percent per year). Growth in secondary energy emissions can be explained by growth in secondary energy use (E) and change in carbon dioxide intensity (CO_2/E). Over the period from 1990 to 1995, secondary energy use grew by 7.5 percent (or an average of 1.5 percent per year) from 6882 petajoules to 7400 petajoules. At the same time, the carbon dioxide intensity of energy use declined 2.3 percent (or 0.5 percent per year), mostly as a result of a fuel shift from oil products to natural gas, wood waste and pulping liquor.

Growth in secondary energy use was most influenced by growth in activity levels in each end-use sector. Had only the level of activity changed in each sector from 1990 to 1995, while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 637 petajoules, rather than the actual 518 petajoules.

Shifts in the structure of intra-sectoral activity (e.g., between industrial subsectors or between commercial building types) contributed to increased secondary energy use since 1990. In general, over this period, the distribution of sector activity shifted toward more energy-intensive components of the Canadian economy. This shift contributed 193 petajoules to the increase in secondary energy use.

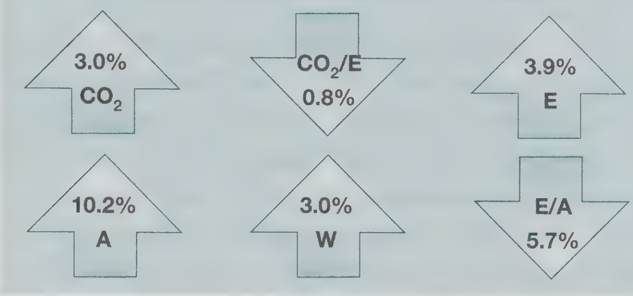
Weather also contributed to increased secondary energy use in the residential and commercial sectors. Although warmer than Environment Canada's 30-year annual average (1951 to 1980), the winter of 1995 was colder than the winter of 1990, leading to increased space-heating requirements and contributing to increased secondary energy use by 52 petajoules. The summer of 1995 was also warmer than the summer of 1990, contributing to increased energy use for space cooling.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had energy intensity remained at its 1990 level in each end-use sector and only activity levels, structure and weather changed, secondary energy use would have been 308 petajoules higher in 1995 than it actually was.

Residential Sector

Residential energy use accounts for 19 percent of secondary energy use and almost 14 percent of carbon dioxide emissions from secondary energy use. From 1990 to 1995, emissions resulting from residential energy use increased by 3 percent (or an average rate of 0.6 percent per year). Growth in residential emissions can be explained by growth in residential energy use and change in carbon dioxide intensity. Over the period, residential energy use increased by 51 petajoules or by almost 4 percent (or 0.8 percent per year), whereas the carbon dioxide intensity of residential energy use declined by 0.8 percent (or 0.2 percent per year), mainly due to a fuel shift from oil to natural gas to meet space- and water-heating requirements.

THE ENERGY/EMISSIONS BAROMETER—RESIDENTIAL



The change in residential energy use was largely influenced by growth in economic activity (A) (the number of households), which increased by 10.2 percent (or an average annual rate of 2.0 percent). Had all factors remained at 1990 levels and only activity changed, energy use would have increased 2 1/2 times more than it actually did.

Weather (W) contributed to an increase in space-heating energy use of 40 petajoules as the winter of 1995 was colder than the winter of 1990. The summer of 1995 was warmer than the summer of 1990. However, the impact of weather on space-cooling demand was negligible given that residential space cooling accounts for less than 1 percent of the energy requirements in this sector.

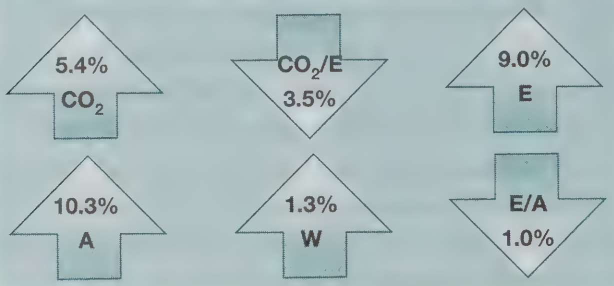
The effect on energy use of a strong decline in energy intensity (E/A) of 125 petajoules over the period partially offset the increase in energy use associated with weather and growth in activity. The decline in energy intensity was largely the result of improvements in the energy efficiency of space-heating equipment and appliances. For example:

- mid- and high-efficiency heating equipment, which accounted for only 37 percent of shipments of natural gas heating equipment in 1990, captured 100 percent of shipments by 1995; and
- the average unit energy consumption of new refrigerators in 1995 was 35 percent less than that of units sold in 1990.

Commercial Sector

Commercial energy use accounts for 13 percent of secondary energy use and almost 9 percent of emissions from secondary energy use. From 1990 to 1995, carbon dioxide emissions resulting from commercial energy use increased by 5.4 percent (or an average rate of 1.0 percent per year). The increase in emissions was the result of a 9 percent (or 1.7 percent annually) increase in energy use and the offsetting effects of a 3.5 percent (or rate of 0.7 percent per year) decline in the carbon dioxide intensity of commercial energy use. The decline in carbon dioxide intensity was due in large part to a fuel shift from oil to natural gas for space- and water-heating applications.

THE ENERGY/EMISSIONS BAROMETER—COMMERCIAL



As with the residential sector, the change in commercial energy use was primarily influenced by growth in economic activity (measured as the growth in floor area), which increased by 10.3 percent (or an average annual rate of 2.0 percent). Weather, and to a lesser degree structure, also contributed to increased energy use.

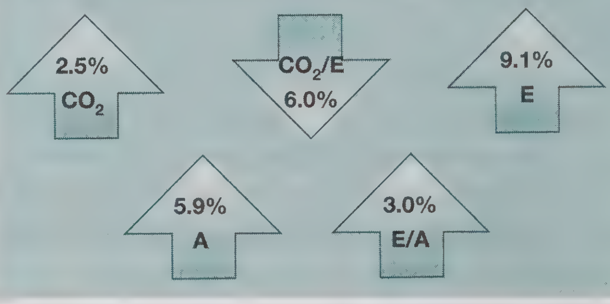
Energy intensity was the only factor that worked toward offsetting growth in energy use. The effect of energy intensity on energy use declined by 2.6 percent. The energy intensity effect was the result of increased energy efficiency of buildings and equipment, improved energy management practices of occupants, as well as a decline in occupancy rates.

Industrial Sector

Industrial energy use accounts for 39 percent of secondary energy use and 31 percent of emissions from secondary energy use. From 1990 to 1995, carbon dioxide emissions resulting from industrial energy use increased by 2.5 percent (or an average rate of 0.5 percent per year). While growth in energy use in this sector had a large impact on the change in emissions, the change in the carbon dioxide intensity of energy use was strongest in the industrial sector. Over the period, industrial energy use increased by 241 petajoules or by about 9.1 percent (or 1.8 percent per year). The carbon dioxide intensity of industrial energy use declined by 6 percent (or 1.2 percent per year) offsetting two-thirds of the impact of increased energy use on emissions.

The decline in industrial carbon dioxide intensity occurred as a result of a fuel shift from oil products to wood waste, pulping liquor and electricity. The shift to wood waste and pulping liquor was concentrated in the pulp and paper industry, where its fuel share increased by 6 percentage points from 1990 to 1995.

THE ENERGY/EMISSIONS BAROMETER—INDUSTRIAL



The change in industrial energy use was influenced by the growth in economic activity (measured as gross domestic product) over the

period 1990 to 1995 and by changes in the mix of activity. Industrial activity, which increased by 5.9 percent (or an average rate of 1.2 percent per year), contributed to an increase in energy use of 157 petajoules. The shift toward more energy-intensive industries also contributed to an increase in energy use of 2.6 percent, or 68 petajoules.

Although the effect of energy intensity gave rise to a modest increase in energy use of less than 1 percent, significant improvements in energy efficiency occurred over this period. Examples of these trends in energy efficiency were observed in:

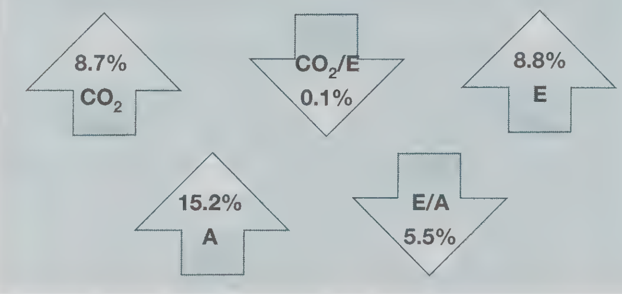
- the pulp and paper industry, where there was a shift from chemical and mechanical pulping to recycling, a process which uses about 17 to 23 percent of the energy required for pulp production;
- the iron and steel industry, where there have been continuous shifts to the electric-arc furnace technology, which uses 100 percent scrap metal and about 13 percent of the energy of an integrated mill, and shifts from ingot casting to continuous casting, which can reduce the energy requirements of the casting process by 50 to 90 percent;
- aluminum production, where old Soderberg-type smelters, which use 18 or 19 megawatt-hours of electricity per tonne of aluminum, were replaced by more efficient smelters, which use as little as 14 megawatt-hours per tonne of aluminum; and
- the cement industry, where the use of more efficient dry kiln technologies such as preheaters and precalciners use between 3.3 and 3.6 gigajoules per tonne of clinker compared to long dry kilns and wet kilns, which use between 4.5 to 5.3 and 6.0 to 6.3 gigajoules per tonne of clinker, respectively.

Transportation Sector

Transportation energy use, which accounts for almost 27 percent of secondary energy use and 43 percent of emissions from secondary energy use, includes two components: the energy used to move people—passenger transportation—and goods—freight transportation. This sector is divided into four mode segments: road, rail, air and marine.

From 1990 to 1995, carbon dioxide emissions resulting from transportation energy use increased by 7.9 percent (or an average rate of 1.5 percent per year). Transportation energy use increased by 146 petajoules or by 8.0 percent (or an average rate of 1.5 percent per year), whereas the change in the carbon dioxide intensity of transportation energy use was negligible.

THE ENERGY/EMISSIONS BAROMETER—PASSENGER TRANSPORTATION

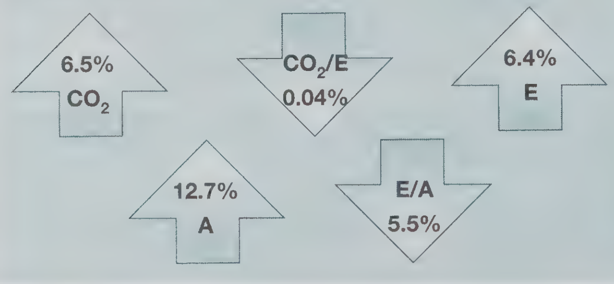


Passenger transportation energy use, which accounts for 65 percent of transportation energy use, increased by almost 9 percent (or 1.7 percent per year) from 1990 to 1995. This change was influenced by the offsetting impacts of growth in economic activity (measured as passenger-kilometres), which increased by 15 percent, and energy intensity, which alone would have led to a decline in energy use of about 4.7 percent.

From 1990 to 1995, energy intensity declined in the light vehicles segment (cars and light trucks) of road passenger transport energy due

to the penetration of more efficient vehicles into the vehicle stock. The average fuel economy of new vehicles improved by 1.9 percent (or 0.4 percent per year) from 1990 to 1995 (from 10.3 to 10.1 litres per 100 kilometres). Moreover, the fuel economy of the stock of vehicles improved by 3.7 percent (or 0.8 percent per year) from 1990 to 1995 (from 10.7 to 10.3 litres per 100 kilometres). These gains have occurred in the face of a trend toward heavier and more powerful vehicles in the 1990s.

THE ENERGY/EMISSIONS BAROMETER—FREIGHT TRANSPORTATION



Freight transportation energy use increased by 42 petajoules or 6.4 percent (or an average rate of 1.3 percent per year) between 1990 and 1995. Had all factors except activity (measured as tonne-kilometres) remained at their 1990 levels, freight transport energy use would have increased by 82 petajoules. The effect of structural shifts, away from both marine and rail toward trucks, contributed to an increase in energy use by 104 petajoules. If energy intensity had not declined, freight transportation energy use would have been 116 petajoules higher in 1995.

An End-Use Perspective on Emissions from Electricity Generation

The analysis in this report focuses on end-use energy demand. No carbon dioxide emissions arise from electricity at its point of use. However, the use of electricity at the end-use level requires the generation of electricity, which produces emissions. In order to give an indication of the level of emissions resulting from electricity generation, an analysis of sectoral emission trends was undertaken where electricity use is attributed an emissions factor reflecting the average mix of fuels to generate electricity.

Emissions under the electricity end-use emissions scenario (ES) were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the no electricity end-use emissions scenario (NES), where there are no carbon dioxide emissions associated with electricity use at the end-use level.

Relative to NES, carbon dioxide emissions from secondary energy use increased less in ES (i.e., 5.1 percent in NES versus 4.1 percent in ES). The smaller change in ES was the result of a decline in the carbon dioxide intensity of secondary energy use brought on by a decline in the carbon dioxide intensity of electricity over the period (from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995). The decline in the carbon dioxide intensity of electricity was due to a shift in fuels used to produce electricity from coal and heavy fuel oil to natural gas and nuclear.

At the sector level, growth in residential emissions over the period declined by 0.4 percent in ES compared to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

Chapter 1

Scope of the Report

HIGHLIGHTS

- This report tracks market trends in energy efficiency, energy use and greenhouse gas emissions in the four major end-use sectors—residential, commercial, industrial and transport—over the period 1990 to 1995.
- The analytical approach relies on various factual and analytical indicators and a factorization method to describe the trends and explain the factors underlying them.
- The quality and quantity of data upon which the analysis is based varies greatly across sectors. To improve these data, Natural Resources Canada has implemented the National Energy Use Database Initiative. The role of this initiative is to establish processes for the collection of data that will allow for a better understanding of energy use in Canada.

1.1 Introduction

In 1992, Canada signed and ratified the Framework Convention on Climate Change (FCCC). Under the FCCC, Canada and over 150 other countries agreed to work toward returning their own greenhouse gas emissions to 1990 levels by the year 2000. A key element of most countries' strategy to meet this objective is the promotion of greater energy efficiency in all sectors of the economy.

In Canada, governments at all levels have programs to reduce the market barriers to energy efficiency and to accelerate the development and adoption of more energy-efficient technologies. The National Action Program on Climate Change (NAPCC) outlines the federal-provincial strategy for achieving the emissions goal and provides guidance for action beyond the end of the century. Under NAPCC, Canada has committed itself to the development of indicators to measure its progress toward meeting national objectives.[1]

This report, the first update of *Energy Efficiency Trends in Canada,* published in April 1996,[2] delivers on Canada's commitment to track market trends in energy efficiency and energy use and to understand its role in the growth of greenhouse gas emissions. An improved understanding of these relationships will, in turn, assist policy-makers in developing more effective responses to climate change.

As with its predecessor, this report covers the four major end-use sectors: residential, commercial, industrial and transportation. The three principal changes in this report compared to the 1996 report are as follows:

- Analysis of energy end-use related greenhouse gas emissions. The 1996 report included an overview section on emissions

1 Government of Canada, *Canada's National Action Program for Climate Change*, Ottawa, Ontario, 1995, Chapter 5.

2 Natural Resources Canada, *Energy Efficiency Trends in Canada*, Ottawa, Ontario, April 1996.

for the entire economy. This report extends the analysis of emissions to the four major end-use sectors.

- Analysis focuses on the 1990 to 1995 period. The 1996 report focused mainly on the 1984 to 1994 period, with one chapter devoted to analysis of the 1990 to 1994 period. This report is focused entirely on the 1990 to 1995 period. The latter year is the most recent year for which actual energy use data are available, while the former is the base year against which Canada's commitment under the FCCC is to be assessed. A new edition of this report will be published annually to update the analysis using the most recent information available.
- Emissions electricity production re-allocated to end-use sectors. The analysis in this report focuses on end-use energy demand. No carbon dioxide emissions arise from electricity at its point of use. However, the generation of electricity to meet end-use demand produces emissions. In order to give an indication of the level of emissions from electricity generation, Chapter 7 is devoted to the analysis of sectoral emission trends where electricity use is attributed an emissions factor reflecting the average mix of fuels to generate electricity.

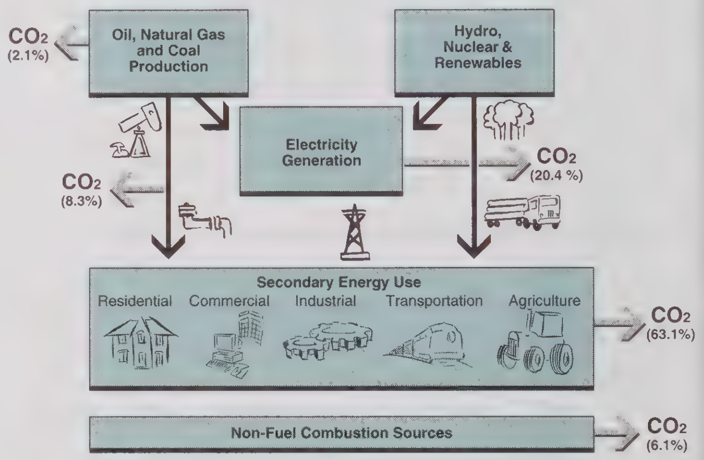
The rest of this chapter describes the relationship between energy efficiency, secondary energy use and greenhouse gas emissions, and the approach and the data used in this report to model this relationship. The rest of the report will first describe the results of the analysis for total secondary energy use and then the sector-by-sector results.

1.2 The Approach

The objective of this report is twofold: first, to understand the influence of the factors affecting energy use and emissions; and second, to explain the contribution of changes in energy efficiency (using energy intensity as a proxy) to the evolution of secondary energy use and greenhouse gas emissions.

Before presenting the analysis, it is important to note the following about its scope. First, this report deals primarily with secondary energy use and the emissions resulting from this use; it does not examine energy use or emissions from the production of energy. Second, energy-related carbon dioxide emissions at the secondary level are used as a proxy for total energy-related greenhouse gas emissions from the same sectors.[3] Future reports will strive for a more comprehensive coverage of greenhouse gas emissions resulting from the use of energy at the secondary level.

Figure 1.1
The Relationship Between Secondary Energy Use and Carbon Dioxide Emissions[4]



The relationship between secondary energy use and carbon dioxide emissions is illustrated in Figure 1.1. The figure shows that emissions originate from secondary energy consumption but also from non-combustion uses of energy

3 Carbon dioxide emissions accounted for 81% of total greenhouse gas emissions in Canada in 1995.

4 Figures in parentheses show share of total carbon dioxide emissions in 1995.

(industrial processes), electricity generation and oil and gas production. Sixty three percent of the total carbon dioxide emissions in Canada in 1995 occurred as a result of energy use at the secondary or end-use level.[5]

At the secondary level, most energy is used in four major sectors (residential, commercial, industrial and transportation) to meet various end uses (e.g., space and water heating). The consumption of energy to meet these end-use requirements produces greenhouse gas emissions. The level of emissions varies according to the quantity and type of fuel used. The quantity of fuel used is directly related to the level of energy efficiency.

1.2.1 Types of indicators

As with its predecessor, this report uses a variety of indicator types to explain the role of energy efficiency in the evolution of secondary energy use and emissions. These indicators are structured hierarchically from the most aggregate to the most disaggregate.

An indicator is an index or any group of statistical values (such as the level of employment) that taken together give an indication of the health of the economy. Energy use indicators measure the status of a specific segment of the economy. Indicators can provide a link between what we observe and the reasons for what we observe. The challenge is to improve these linkages.

We have categorized the indicators used in this report into two major types: factual and analytical.

Factual Indicators

In this report, factual indicators are used to *describe* a situation with respect to either energy use or emissions, the major variables explained in the study. For example, we can use these indicators to show how much energy is used and where it is used or the level of emissions in a given sector. Factual indicators can be further categorized into two types: snapshot and trend, according to the time dimension they portray. Snapshot indicators describe a situation at a point in time, while trend indicators describe the evolution of a situation over time.

Analytical Indicators

Analytical indicators are used to *explain* a situation. The two types of analytical indicators used extensively in this report are factorial and causal indicators. Factorial indicators are based upon an analysis of time series data where the source of change in one variable is attributed to the principal factors affecting that change. In this report, we have applied this approach to the change in energy use in each sector and, in so doing, have attributed to activity, structure, weather and energy intensity a contribution to the change in energy use. This factorization methodology is described in more detail below and in Appendix B.

Causal indicators are also used to explain change in a particular variable. For example, energy price is a causal indicator that can explain change in the level of energy use.

In this report, we distinguish the two types of analytical indicators to emphasize the fact that in the factorization analysis the principal factors affecting change in energy use are strictly and quantitatively related to the change in energy use. To explain cause and effect in other instances, we use a more casual approach of qualitatively contrasting the trend in causal analytical indicators with the trend in the variable being explained. Table 1.1 illustrates the different types of indicators used in this report.

5 From this point on in the report, except for Chapter 7, any reference to emissions implies energy-related carbon dioxide emissions from secondary energy use.

Table 1.1
Illustration of the Types of Indicators Used in this Report

Factual	Analytical
Snapshot	**Factorial**
energy use by type of dwelling, 1995	activity effect, 1990–1995
energy use by end use, 1995	structure effect (end-use mix), 1990–1995
carbon dioxide emissions, 1995	energy intensity effect, 1990–1995
Trend	**Causal**
energy intensity index, 1990 to 1995	housing stock by vintage, 1990 and 1995
energy use index, 1990 to 1995	gas furnace shipments by efficiency, 1990 and 1995
carbon dioxide emissions index, 1990 to 1995	degree-day index, 1990 to 1995

1.2.2 Structure of the analysis

This section describes the structure within which the various types of indicators are used in the rest of the report.[6] This structure deals, first, with the analysis of emissions trends, and second, with the analysis of energy use and efficiency trends.

Analysis of Trends in Carbon Dioxide Emissions

Total greenhouse gas emissions can be expressed as the sum of emissions from non-combustion uses of energy, electricity generation, oil and gas production and secondary or end-use energy consumption. As noted earlier, the focus of this report is secondary energy use. The importance of emissions from secondary energy use relative to total emissions is documented in Figure 1.1, page 2.

The structure of the analysis of emissions from the use of energy to meet end-use requirements, which is presented in this report, can be summarized by the following three equations:

$$CO_2\ sec = CO_2\ res + CO_2\ com + CO_2\ ind + CO_2\ tran \quad (1)$$

where

CO_2 sec: carbon dioxide emissions from secondary energy use
CO_2 res: carbon dioxide emissions from residential energy use
CO_2 com: carbon dioxide emissions from commercial energy use
CO_2 ind: carbon dioxide emissions from industrial energy use
CO_2 tran: carbon dioxide emissions from transportation energy use

The elements of equation 1 are presented in Chapter 2, which provides an overview of trends in emissions and energy use at the aggregate secondary level.

In each energy-consuming sector, energy-related emissions are expressed as the product of energy use and the carbon dioxide intensity of this energy use. This is written as:

$$CO_2 = E \times (CO_2/E) \quad (2)$$

where

CO_2: carbon dioxide emissions
E: energy use
CO_2/E: carbon dioxide intensity of energy use

In turn, change (Δ) in carbon dioxide emissions is approximated[7] by the sum of growth in energy use and carbon dioxide intensity:

$$\Delta CO_2 = \Delta E + \Delta(CO_2/E) \quad (3)$$

6 Many of the methods used in this report are inspired by the work completed at Lawrence Berkeley Laboratory (LBL) in Berkeley, California, and at l'Agence de l'environnement et de la maîtrise de l'énergie (ADEME) in Paris, France. The following two publications illustrate this work: Schipper, L.; Myers, S.; Howarth, R.; Steiner, R.,: *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge University Press, Cambridge, Great Britain, 1992; and ADEME, *Cross Country Comparisons on Energy Efficiency Indicators: Phase 1*, Paris, France, November 1994.

7 The only difference between the sum of factors on the right-hand side of equation 2 and the total growth in CO_2 will be the product of the growth in E and CO_2, i.e., ($\Delta E \times \Delta CO_2$). This amount, and hence the difference between both sides of the equation, will vary in size as a function of the size of both ΔE and ΔCO_2.

Equations 2 and 3 are sector specific and are used to structure the emissions component of the analysis presented in Chapters 3 to 6, which cover the four end-use sectors. The analysis of emissions presented in each of these chapters elaborates on the factors underlying growth in both energy use and carbon dioxide intensity of energy use,[8] thereby documenting the forces driving growth in energy-related carbon dioxide emissions.

Analysis of trends in energy use and efficiency

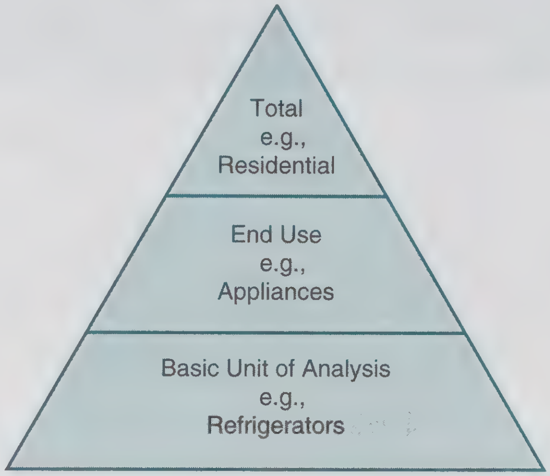
The challenge of this report is to isolate and then relate trends in energy intensity to trends in aggregate energy use and ultimately to trends in emissions. This calls for a set of macro and micro indicators. The relationship between such indicators is complex. Because of this lack of transparency, one can often lose sight of the purpose when presenting indicators and, hence, limit the explanatory power of the indicator approach. The Indicator Pyramid is a useful tool to establish the relationship between the various indicators for a given sector and the hierarchy between indicators representing different levels of aggregation.

Figure 1.2 illustrates the Indicator Pyramid for the residential sector. The pyramid presents energy use at increasing levels of detail from its most aggregate representation to an account of energy use by equipment type. Indicator pyramids for other sectors are presented in Appendix B.

At the top level of the pyramid, one can examine residential energy use and assess aggregate sector-specific indicators, such as residential energy use per household. Also, one can look at the energy use associated with different categories of service being provided and examine such indicators as appliance energy use per household or heating energy use per household.

At the most disaggregated level, one can examine indicators related to specific pieces of equipment, such as energy use per unit of output of a refrigerator.

Figure 1.2
The Indicator Pyramid: A Residential Sector Illustration



While the pyramid serves to structure the indicators, it does little to explain the contribution of changes in one indicator to changes in another. For this purpose, we use the factorization methodology.

The factorization methodology attributes the change in energy use at any level of the pyramid to four factors: activity, mix of activity, weather, and energy intensity. For example, a factorization of total residential energy use would attribute the change in energy use to a growth in households (activity), to the change in the end-use mix (structure), to a change in weather and to the change in energy intensity of each of the end uses.

Increases in sector activity lead to increased energy use and emissions in that sector. In the residential sector, for example, all other things remaining the same, an increase in the

8 The carbon dioxide intensity of energy use is a weighted average of fuel-specific carbon dioxide intensities. The weights used in the calculation of this intensity for a given sector are the shares of energy demand accounted for by each fuel in that sector. In this report, analysis of changes in the carbon dioxide intensity of energy use in each sector will focus on a review of shifts in the fuel mix for that sector.

Table 1.2
Definitions of Activity and Structure Used in this Report, by Sector

Sector	Activity	Structure
Residential	number of households	end-use mix: e.g., space heating, space cooling, appliances, lighting and water heating
Commercial	floor space	building type: e.g., office, retail stores and hotel/restaurant
Industrial	gross domestic product	sector mix: e.g., pulp and paper, other manufacturing and iron and steel
Transportation	passenger- and freight-kilometres	mode mix: road, rail, air and marine.

number of households would have the effect of increasing energy use.

A shift in the structure of activity toward more energy-intensive components of activity, all other things the same, leads to increased energy use and emissions. For example, if the distribution of activity in the industrial sector shifts from construction to the pulp and paper industry, an increase in industrial energy use will result, as the former is much less energy-intensive than the latter. The definitions of activity and structure used in this report for each sector are described in Table 1.2.

Fluctuations in weather lead to changes in space-heating and -cooling requirements. A colder winter or a warmer summer can both lead to increased energy use. The weather effect is most significant in the residential and commercial sectors where both heating and cooling requirements are important.

For the purpose of this report, energy intensity (energy use divided by activity) is used as a proxy for energy efficiency. Technical energy efficiency can only be measured at the "micro" level (e.g., the energy efficiency of a refrigerator or a furnace). While the sectoral pyramids allow us to "drill" down to significant levels of detail, even the most disaggregate energy intensities presented in this report will reflect factors in addition to energy efficiency. In the industrial sector, for example, the most disaggregate energy intensity is an industry-specific intensity. This intensity reflects, in addition to energy efficiency, shifts in the mixes of product, process and/or fuel for that industry.

Nevertheless, by isolating the importance of activity, structure and weather, it is possible to estimate the impact of energy intensity on changes in energy consumption. The change in energy intensity can be interpreted as an "indicator" of the change in energy efficiency, which is only directly measurable at the greatest level of disaggregation. However, the reader should keep in mind that the estimated change in energy intensity reflects technological efficiency improvements as well as the energy efficiency improvements that result from fuel switching and behavioural change, among others.

1.3 The Data

While it is necessary to base the study on a sound analytical framework, it is not a sufficient condition to produce reliable and defensible analysis of changes in energy use. The availability of good quality data on energy use, emissions, and activity levels in each end-use sector is crucial to the production of high-quality analysis.

The strength of this report rests upon explicit recognition of the importance of both the method and the quality of the data upon which the results are based. Therefore, this section provides an overview of the strengths and

weaknesses of the major data used in the report. For a description of data collection activities that will lead to better quality data in the future, see sidebar bottom right.

The detailed sources and definitions of the data presented in the report are documented in Appendices A, B, C and D.

Activity

In the residential and industrial sectors, activity measures are from Statistics Canada. In general, these measures are quite adequate and well aligned with the coverage of energy use. Activity measurement difficulties arise in the commercial and transportation sectors.

In the commercial sector, the measure of activity is floor space. The set of floor space data presented in this report includes very little actual data on floor area. The estimates of floor space result from an estimation procedure that uses data on investment flows/capital expenditures by structure and asset type, and average construction cost data. Until a national survey of floor space is available, efforts will focus on the collection of existing data on floor space that will be integrated into this estimation procedure.

In the transportation sector, two measures of activity are used. The first pertains to the movement of people (passenger-kilometres) and the second to the movement of goods (tonne-kilometres). Unfortunately, the data available to create either of these measures are partial.

Passenger-kilometre data for air and rail travel are available from Statistics Canada. Light vehicle and bus passenger-kilometres are estimated from data on distance travelled and occupancy ratios. For both of these variables, data are only available for selected years, and time series have been constructed to "fill in" for missing years. For light vehicles, the availability of data from the *National Private Vehicle Use Survey* should greatly improve the measurement of activity in this segment in future reports.

Tonne-kilometre data are available from Transport Canada for marine freight activity and from Statistics Canada for rail freight activity and part of trucking activity. The coverage of trucking activity has been expanded in this report compared with the 1996 Report, but it remains partial. We hope that continued research will help us improve the measure even further for the next report.

Energy use

Sectoral energy use data are taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD), Canada's official energy balance. These data are available by fuel type for the major end-use sectors.

CANADA'S NATIONAL ENERGY USE DATABASE INITIATIVE

The reliability of energy use analysis largely depends on the quality of the data available to undertake such analysis. Without a process to collect high-quality information on a regular basis, the analysis will not progress.

Recognizing the state of data collection in the area of energy use, Natural Resources Canada (NRCan) has made data collection an integral part of its Efficiency and Alternative Energy Program through an initiative called the National Energy Use Database (NEUD) Initiative. Through this initiative, processes have been established for the regular collection of detailed data on energy use and the characteristics of energy-using equipment and buildings in all sectors of the Canadian economy.

Under NEUD, the following principal surveys have been completed to date: the *Survey of Household Energy Use* (1993), *New Housing Survey* (1994), *National Private Vehicle Use Survey* (1995/96) and *Industrial Consumers of Energy* (1995/96). Data from these surveys are quoted throughout this report. Over the next few years, NRCan will continue integrating these new data into its analysis.

In addition to designing and funding these surveys, NRCan has established, under NEUD, five Data and Analysis Centres, each of which specializes in a specific sector of energy use. This ensures continuity in the analysis of energy use in Canada.

More information on the survey activities of the NEUD and on the Data and Analysis Centres is available on request.

In the industrial sector, QRESD data are available for 10 branches of industry. This means that all of the industrial energy use

data presented in this report are taken from the QRESD. In other sectors, specific energy use data below the aggregate sector amount are estimated through an end-use modelling approach.

In the residential sector, energy demand estimates for each end use are developed through a calibration process that takes into account the aggregate energy use and a large amount of detailed data on the characteristics of buildings and household equipment.

In the commercial sector, a modelling approach is also used to estimate end-use demand by building types. These end-use estimates are arrived at judgmentally through discussion with sector experts. It is recognized that, among the four sectors, energy use data problems are most limiting in the commercial sector.

In the transportation sector, the split in energy use between passenger and freight transport is estimated using a modelling approach that calibrates vehicle stock characteristics, distance travelled and efficiency data to aggregate road transport sector energy use. Energy use data for rail, air and marine are available from QRESD.

Greenhouse gas emissions

The greenhouse gas emissions data presented in this report are the result of multiplying the energy use data by emissions factors taken from Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990 to 1995*. The differences between total sector-specific emissions presented in this report and those presented by Environment Canada arise as a result of differences in sectoral definitions (i.e., re-allocations of QRESD energy data from one category to another by Environment Canada or Natural Resources Canada or both). These differences are documented in Appendix D.

1.4 Overview of the Report

Chapter 2 reviews aggregate trends in secondary energy use and emissions from 1990 to 1995 and provides an overview of the contribution of sectoral trends to these aggregate trends.

Chapters 3 to 6 provide an in-depth analysis of the trends in emissions and energy use for each sector. The analysis of emissions relates growth in emissions over the 1990 to 1995 period to the growth in energy use and the change in the carbon dioxide intensity of energy use. The analysis of energy use attributes to activity, structure, weather and energy intensity a contribution to the change in energy demand. Furthermore, the sources of change in the latter three determinants are reviewed in detail in each chapter.

Chapter 7 presents an analysis of trends in emissions from secondary energy use in which emissions from electricity generation are attributed to the end-use sectors where the energy is consumed.

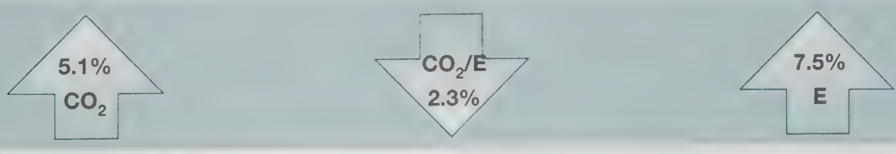
This report describes only part of the data and indicators collated for the analysis. All of the data prepared for this report are available in a database on the Internet by searching for *Energy Efficiency Trends in Canada* at **http://eeb-dee.nrcan.gc.ca**

Chapter 2

Economy-Wide Trends in End-Use Energy, Energy Efficiency and Emissions

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from secondary energy use increased by 5.1 percent from 1990 to 1995, as the impact of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity (CO_2/E) of secondary energy use decreased by 2.3 percent from 1990 to 1995 due to a shift toward the use of fuels with a lower carbon content. In the absence of this fuel shift, carbon dioxide emissions would have been 7 megatonnes higher in 1995 than they actually were.
- Secondary energy use (E) was the major cause of the rise in carbon dioxide emissions, as it increased by 7.5 percent for a total of 518 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 22 megatonnes lower in 1995 than they actually were.
  - Increases in activity in the four major energy- using sectors caused energy use to increase. In the absence of activity growth from 1990 to 1995, energy use would have been 637 petajoules lower in 1995 than it actually was.
  - The change in the mix of activity toward more energy-intensive segments also contributed to increased energy use. In the absence of a change in the mix of activity, energy use would have been 193 petajoules lower in 1995 than it actually was.
  - Colder weather in 1995 compared to 1990 led to higher energy use. Had the weather been the same in 1995 as it was in 1990, energy use would have been 52 petajoules lower in 1995 than it actually was.
  - Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had all other factors remained constant over the period and only energy intensity changed, secondary energy use would have decreased by 308 petajoules from its 1990 level.



As noted in Chapter 1, emissions from secondary energy use in Canada account for about two-thirds of all carbon dioxide emissions. At the secondary level, energy consumption and associated carbon dioxide emissions are concentrated in five sectors: residential, agriculture, commercial, industrial and transportation. The transportation sector accounts for the largest share of carbon dioxide emissions from secondary energy use (43 percent), followed by industrial (31 percent), residential (14 percent), commercial (9 percent) and agriculture (4 percent).[1]

1 The definition of the energy use included in each of the sectors for the purpose of this report is different from the sectoral definitions adopted by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Definitional differences between this report and Environment Canada's report and their implications for the level of emissions for each sector are documented in Appendix D.

Table 2.1 summarizes the changes in carbon dioxide emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995 for total secondary energy use and each end-use sector. From 1990 to 1995, carbon dioxide emissions resulting from secondary energy use increased by a total of 5.1 percent (or an average annual growth rate of 1 percent) from 303.4 megatonnes to 318.7 megatonnes. The most significant change occurred in the transportation sector, where emissions increased by almost 10 megatonnes or by about 8 percent over the period. Commercial sector emissions increased by 5.4 percent over the period, followed by residential (3.0 percent), industrial (2.5 percent) and agriculture[2] (2.2 percent).

The change in carbon dioxide emissions is the result of the change in energy use and its carbon dioxide intensity. In all sectors but agriculture, energy use had the largest influence on the change in emissions from 1990 to 1995. At the total secondary level, energy use grew by 7.5 percent (or an average annual rate of 1.5 percent), from 6882 petajoules to 7400 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 22 megatonnes lower in 1995 than they actually were. The influence of increased energy use on the growth in emissions was partly offset by a decline in the carbon dioxide intensity of secondary energy use of 2.3 percent.

2.1 Trend in the Carbon Dioxide Intensity of Secondary Energy Use

In the absence of the decline in the carbon dioxide intensity of secondary energy use, emissions would have been 7 megatonnes higher in 1995 than they actually were. The decline in the carbon dioxide intensity resulted from a shift in the mix of fuels used to meet this demand. As shown in Figure 2.1, from 1990 to 1995 there was an increase in the shares of natural gas of 1 percentage point and "other fuels" of almost 1 percentage point (mostly wood waste and pulping liquor used in the pulp and paper sector) at the expense of oil products, which declined by almost 2 percentage points. The carbon dioxide intensities of natural gas and wood waste are significantly lower than those of most oil products. As for energy use and energy intensity, further explanations of the reasons underlying the shift in fuel mix at the

Table 2.1
Factors Influencing Growth in Carbon Dioxide Emissions from Secondary Energy Use, 1990–1995

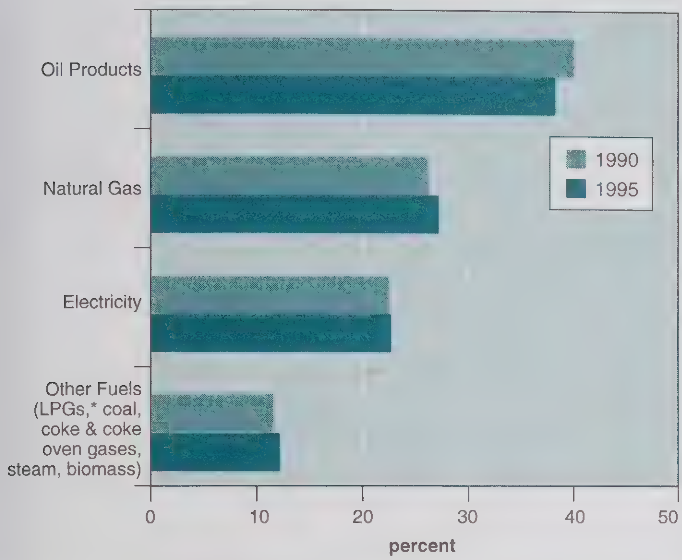
	Carbon Dioxide Emissions (megatonnes)		Carbon Dioxide Emissions	Energy Use (percent change)	Carbon Dioxide Intensity of Energy Use
	1990	1995		1990–1995	
Residential	42.1	43.4	3.0	3.9	-0.8
Commercial	26.7	28.1	5.4	9.0	-3.5
Industrial	96.4	98.9	2.5	9.1	-6.0
Transportation	126.8	136.7	7.9	8.0	--
Agriculture (1)	11.3	11.6	2.2	0.9	1.3
Total	303.4	318.7	5.1	7.5	-2.3

(1) Emissions from agriculture energy use are not analysed further than data in this table for lack of sufficient information.
– Amount too small to be expressed at one decimal.

2 The definition of agriculture energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the agriculture sector in this report are higher than Environment Canada's by 8.9 megatonnes in 1990 and 9.0 megatonnes in 1995. See Appendix D for documentation of differences.

secondary level are presented for each end-use sector in Chapters 3 through 6.

Figure 2.1
Secondary Energy Fuel Shares, 1990 and 1995 (percent)



* liquefied petroleum gases

2.2 Evolution of Secondary Energy Use and its Major Determinants

Secondary energy use accounts for 73 percent of total energy consumption in Canada. The industrial sector accounts for the largest share of secondary energy use (39 percent), followed by transportation (27 percent), residential (almost 19 percent), commercial (13 percent) and agriculture (3 percent).

From 1990 to 1995, energy use grew the fastest in the industrial and commercial sectors, increasing by 9.1 and 9.0 percent, respectively. Strong growth in energy use was also observed in the transportation sector (8.0 percent). Growth in energy use was not as strong in the residential and agriculture sectors where it increased by 3.9 and 1 percent, respectively.

Table 2.2 presents the effect of growth in activity, structure, weather and energy intensity on the growth in secondary energy use from 1990 to 1995. A fifth factor, the interaction effect, is also identified in Table 2.2. This factor results from the interaction between the four other factors. The sidebar below illustrates the relationships that lead to the calculation of this effect.

THE INTERACTION EFFECT

The method used in this report to analyse the contribution to changes in energy use of growth in activity, structural shifts and energy efficiency is a Laspeyre index method. One characteristic of this method is the estimation of an interaction effect. This effect exists as a result of the interdependence between the three main factors.

Although the method used in this report attributes impacts on energy use to the factors of activity, structure, weather, energy intensity and their interaction, the following example illustrates, in simple terms, the relationships that lead to the interaction effect for two factors. The data used are hypothetical:

	year 1	year 2	% change
1. Energy use	10	13	30
2. Activity	5	5.5	10
3. Energy intensity(1./2.)	2	2.36	18.2

The sum of the activity and energy intensity impacts is 28.2 percent. This is 1.8 percentage points short of the total change in energy use of 30 percent that is being explained.

In this example, the 30 percent change in energy use can be attributed as follows:

Activity: 10 percent
Energy intensity: 18.2 percent
Interaction: 1.8 percent

While this is an oversimplification of the interaction effect calculation, it illustrates the basic principle that underlies it.

Many past studies have used different approaches to calculate the influence of activity and intensity on energy use. In some of these methods (e.g., Divisia index), the interaction effect is re-allocated to activity and intensity arbitrarily under the assumption that it is negligible. We have chosen to present the interaction effect separately and have found that the assumption of it being negligible is not always valid.

Additional discussion of the interaction effect is presented in the section titled Notes on Interaction Terms in Appendix B.

It is evident from the data in Table 2.2 that growth in secondary energy use was most influenced by growth in sectoral activity levels. Had only the level of activity changed in each sector from 1990 to 1995 while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 637 petajoules, rather than the actual 518 petajoules.

Table 2.2
Factors Influencing Growth in Secondary Energy Use, 1990–1995 (petajoules)

	Energy Use								
	1990	1995	1995 less 1990 (5)	Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction Effect	Other
Residential	1325	1376	51	134.8	15.8	40.2	-125.3	-14.1	n.a.
Commercial (1)	864	942	77	87.7	3.3	11.5	-22.7	-1.6	-0.8
Industrial	2649	2890	241	156.5	68.3	n.a.	11.3	4.6	n.a
Transportation	1839	1986	146	257.6	105.9	n.a.	-171.4	-37.7	-4.5
Passenger (2)	1195	1300	105	175.6	1.6	n.a.	-55.5	-9.6	-5.2
Freight (3)	645	686	42	82.0	104.3	n.a.	-115.9	-28.1	0.7
Agriculture (4)	205	207	2	N.A.	N.A.	N.A.	N.A.	N.A.	1.9
Total	6882	7400	518	637	193	52	-308	-49	-3

(1) The factorization excludes street lighting. The change in energy use for this component from 1990 to 1995 is shown in the "Other" column.
(2) The factorization was done using motor gasoline equivalency for alternative transportation fuels and excludes the non-airline (commercial/institutional and public administration) air sector. The change in energy use from 1990 to 1995 for the non-airline component (-6.2 PJ) and the difference due to the use of motor gasoline equivalency for alternative transportation fuels (1.0 PJ) are shown in the "Other" column.
(3) The factorization was done using motor gasoline equivalency for alternative transportation fuels. The difference in energy use due to the use of motor gasoline equivalency for alternative transportation fuels (6.1 PJ) is shown in the "Other" column.
(4) The factorization analysis was not done for the agriculture sector. The change in energy use for this component from 1990 to 1995 is shown in the "Other" column.
(5) The change in energy use between 1990 and 1995 shown in this column and the sum of activity, structure, weather, energy intensity and interaction for passenger and freight transport are slightly different because of i) the exclusion from the factorization analysis of the non-airline segment in passenger transport and ii) the fact that the factorization of energy use for these sectors was done using motor gasoline equivalency values (see Chapter 6 footnotes for more detail). The transport sector differences are reflected at the secondary energy use level; other differences excluded from the factorization such as agriculture and street lighting are included under "other."

Structure, or the mix of activity, advanced the increase in secondary energy use since 1990. Structural change over this period favoured a shift in the distribution of sector activity toward more energy-intensive components of the Canadian economy. This shift contributed 193 petajoules to the increase in secondary energy use.

Weather also contributed to the increase in secondary energy use. Although warmer than Environment Canada's 30-year annual average (1951 to 1980), the winter of 1995 was colder than the winter of 1990, leading to increased space-heating requirements and contributing to increased secondary energy use by 52 petajoules.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had energy intensity remained at its 1990 level in each end-use sector and only activity levels, structure and weather changed, secondary energy use would have been 308 petajoules higher in 1995 than it actually was.

At the aggregate secondary level, it is difficult to understand the factors underlying the decline in energy intensity. For this reason, Chapters 3 through 6 review sectoral trends in energy use and energy intensity.

Chapter 3

Residential Sector

HIGHLIGHTS

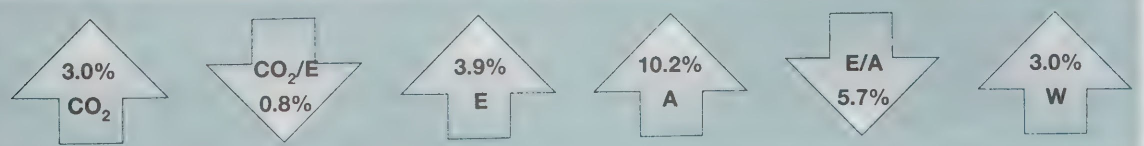
- Carbon dioxide emissions (CO_2) resulting from residential energy use increased by 3.0 percent from 1990 to 1995. Most of this increase is attributable to growth in energy use, although change in the carbon dioxide intensity of energy use offset 21 percent of the impact of energy use.
- The carbon dioxide intensity (CO_2/E) of residential energy use decreased by 0.8 percent from 1990 to 1995 due in large part to a shift toward the use of natural gas and away from the use of oil. In the absence of fuel shifts, carbon dioxide emissions would have been about one megatonne higher in 1995 than they actually were.
- Energy use (E) was the major cause of the rise in residential carbon dioxide emissions, as it increased by 3.9 percent for a total of 51 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions from residential energy use would have been almost 2 megatonnes lower in 1995 than they actually were. The major factors underlying the growth in residential energy use were the following:

– Increases in residential sector activity (A-measured as households) caused energy use to increase. In the absence of activity growth from 1990 to 1995, energy use would have been 135 petajoules lower in 1995 than it actually was.

– The change in the mix of end uses also contributed to increased energy use. In the absence of a change in the mix of end uses, energy use would have been 16 petajoules lower in 1995 than it actually was.

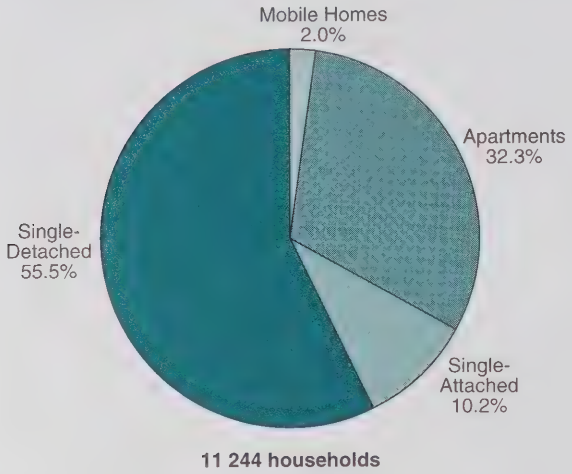
– Colder weather (W) in 1995 compared to 1990 led to higher energy use. Had the weather been the same in 1995 as it was in 1990, energy use would have been 40 petajoules lower in 1995 than it actually was.

– Energy intensity (E/A) was the only factor that kept residential energy use from increasing more than it actually did from 1990 to 1995. Had all other factors remained constant over the period and only energy intensity changed, residential energy use would have decreased by 125 petajoules from its 1990 level.



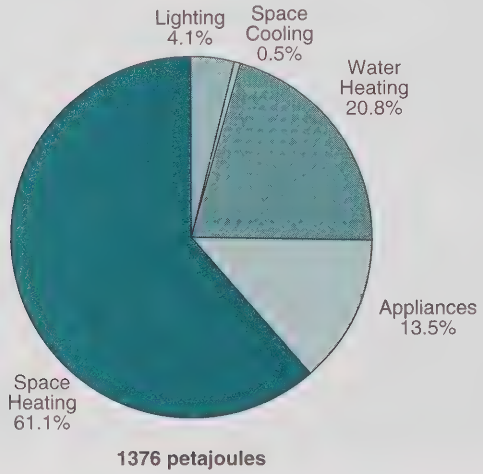
The residential sector includes four major types of dwellings: single-detached, single-attached and mobile homes, and apartments. Figure 3.1 presents the distribution of households according to dwelling type. Single-detached homes and apartments account for 88 percent of total Canadian households.

Figure 3.1
Distribution of Households by Type of Dwelling, 1995 (percent)



Energy is used in Canadian dwellings for space heating and cooling, water heating, appliances and lighting. As shown in Figure 3.2, most of the energy used to meet Canadian household energy needs is associated with space and water heating. Space heating and water heating account for 61 and 21 percent of total residential energy demand, respectively.

Figure 3.2
Distribution of Residential Energy Use by End Use, 1995 (percent)



The shares of space heating and water heating in the distribution of residential sector carbon dioxide emissions[1] by end use are even more dominant than their respective shares of energy use. As shown in Figure 3.3, space heating and water heating together account for virtually all (76.5 and 23.0 percent in 1995, respectively) of residential sector emissions. The remaining end uses are almost entirely electricity based, and given that electricity consumption does not result in carbon dioxide emissions, appliances, space cooling and lighting are responsible for less than one percent of residential sector emissions.

Figure 3.3
Residential Carbon Dioxide Emissions by End Use, 1990 and 1995 (percent)

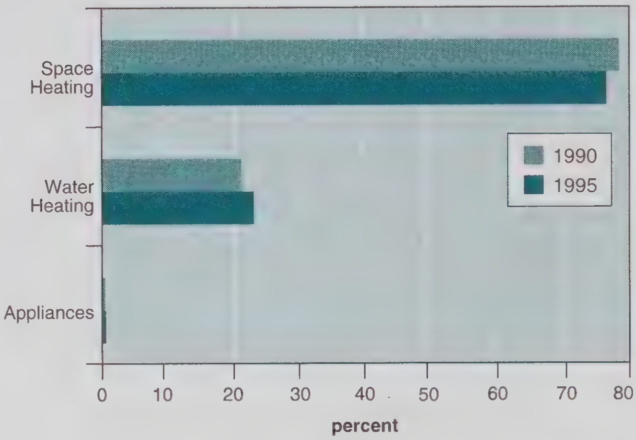


Figure 3.4 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows a 5 percent downturn in the 1991–1992 period, followed by an 11 percent upturn through 1994 and then a 3 percent decline in 1995. In each of these sub-periods, energy use and the carbon dioxide intensity of energy use moved in the same direction as emissions as they both contributed to the change in emissions.

1 The definition of residential energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the residential sector in this report are higher than Environment Canada's by 1.4 megatonnes in 1990 and 1.5 megatonnes in 1995. See Appendix D for documentation of differences.

Figure 3.4
Residential Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

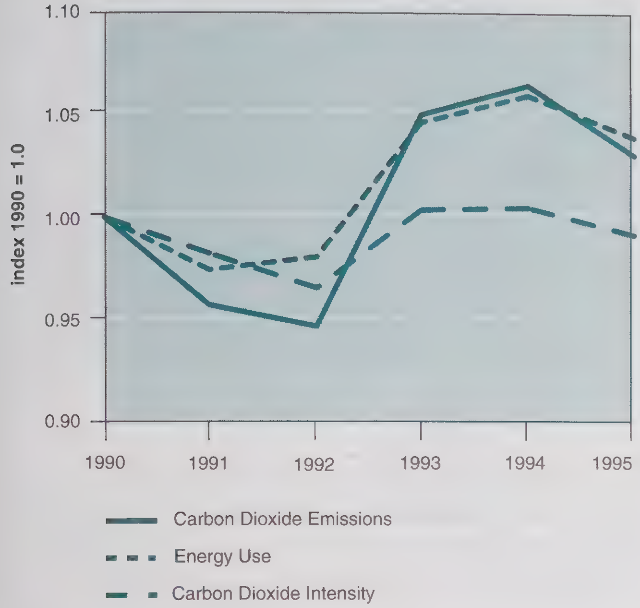
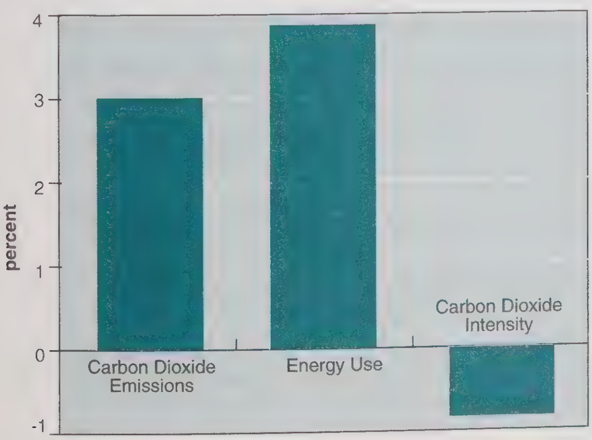


Figure 3.5 shows that carbon dioxide emissions resulting from the combustion of energy to meet residential sector needs increased by 3 percent (or an average growth of 0.6 percent per year), from 42.1 megatonnes in 1990 to 43.4 megatonnes in 1995. Growth in energy use of 3.9 percent (an average of 0.7 percent per year) in this sector had a significant impact on the trend in emissions. The slight decline in the carbon dioxide intensity of energy use over the period offset some of the upward influence of energy use on emissions.

Figure 3.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

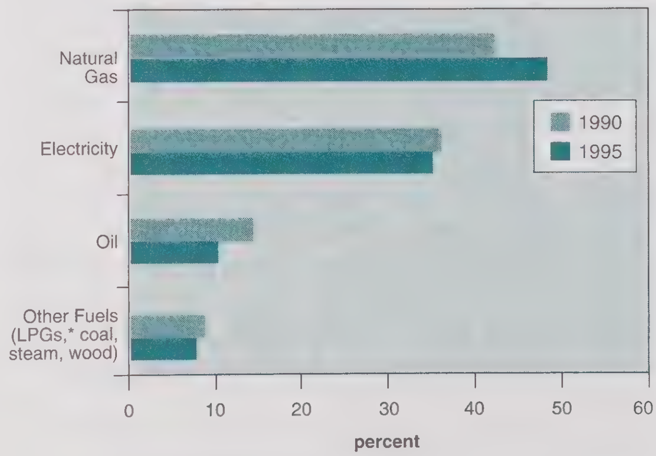


3.1 Trend in the Carbon Dioxide Intensity of Residential Energy Use

Had it not been for the 0.8 percent decline in the carbon dioxide intensity of energy use, residential sector emissions would have grown by 3.9 percent rather than 3.0 percent over the period, representing less than one additional megatonne of emissions in 1995 relative to the actual level of emissions in that year.

The minor decline in the carbon dioxide intensity of residential energy use from 1990 to 1995 reflects a number of offsetting shifts in fuel shares. As shown in Figure 3.6, the most notable of these changes concerns the shift away from oil (4 percentage point decrease) toward natural gas (6 percentage point increase). The shift away from oil, which began in the early eighties in response to oil price increases, has continued over the nineties even though oil prices have remained relatively low during the 1990 to 1995 period. The shift toward natural gas was influenced by wider availability of natural gas and relatively lower prices.

Figure 3.6
Residential Energy Fuel Shares, 1990 and 1995 (percent)



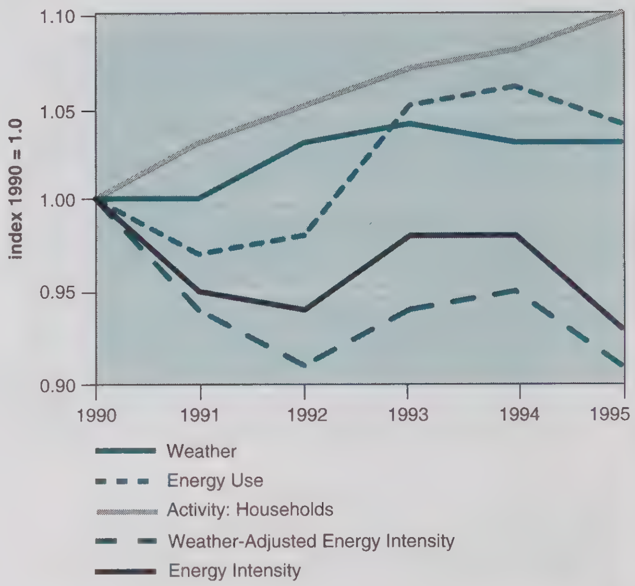
* liquefied petroleum gases

The principal factor underlying the shift toward natural gas in the residential sector was the large increase in its importance as a source of energy for space heating and water heating.

From 1990 to 1995, the share of households using natural gas for space heating increased by 3 percentage points (from 44.6 percent to 47.4 percent), and the share of space heating energy use accounted for by natural gas increased by 7 percentage points (from 50.3 percent to 57.5 percent). Gains in both of these areas were realized mainly at the expense of the use of oil for space heating.

Similarly, the share of households heating water with natural gas increased by 4 percentage points (from 40.2 percent to 44.6 percent), and the share of natural gas in water-heating energy use increased by almost 8 percentage points (from 51.3 percent to 59.2 percent). These changes were at the expense of electricity and to a lesser extent oil.

Figure 3.7
Residential Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



3.2 Evolution of Residential Energy Use and its Major Determinants

Figure 3.7 illustrates the evolution of residential energy use, intensity and activity from 1990 to 1995. Over this period, residential energy use increased by approximately 3.9 percent from 1325 petajoules in 1990 to 1376 petajoules in 1995. The effect on energy use of strong growth in residential sector activity[2] (10.2 percent or an average annual growth rate of 2 percent) and of colder weather in 1995 compared to 1990 was offset by a decline in energy intensity of 5.7 percent (or an average annual decline of almost 1.2 percent).

It is apparent from the data in Figure 3.7 that the trend in residential energy use from 1990 to 1995 is highly correlated with the trend in activity. Year-to-year variations in energy use, on the other hand, are closely linked with changes in weather[3] and energy intensity.

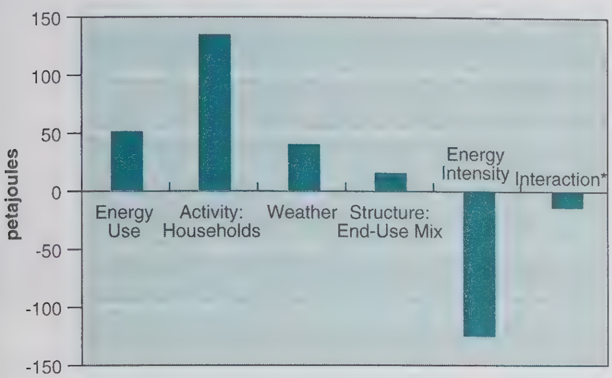
3.2.1 Factors influencing growth in residential energy use

The results of the factorization for the 1990 to 1995 period indicate that residential energy demand increased by 51 petajoules. Among the factors shown in Figure 3.8 as contributing to this change, the level of activity had the greatest impact. In fact, had all other factors (energy intensity, weather and structure) except activity remained constant at their 1990 levels, residential energy use would have increased by 135 petajoules, rather than the observed 51 petajoules.

2 Statistics Canada recently benchmarked the number of households to 1991 Census data. The benchmarking led to revisions in the number of households reported by Statistics Canada. These revisions have been incorporated in this report.

3 The trend in weather helps explain the fluctuations in energy use over the period. A weather index value greater than one indicates the weather was colder than in 1990, whereas an index value less than one indicates the weather was warmer than in 1990. Comparing heating degree-days for 1990 and 1995 to Environment Canada's 30-year annual average (1951 to 1980) indicates that both years were slightly warmer than the average. However, 1995 was colder than 1990.

Figure 3.8
Factors Influencing Growth in Residential Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

The change in the structure (measured as the end-use composition of activity) of the residential sector increased energy use by 16 petajoules between 1990 and 1995. This increase can be attributed to the increase in penetration of appliances and space cooling. Because the penetration rates for space heating, water heating and lighting are each equal to one (i.e., almost all households have these end uses) and the relative energy requirements for space cooling are so small, only the growth in the penetration of appliances over the period 1990 to 1995 significantly impacted on energy use.

Weather had an important impact on growth in energy use (40 petajoules). The 1995 heating season was colder than 1990, resulting in an increase in energy required for space heating. The trend in weather also affected the need for space cooling. Additional energy was required to meet this end use because the summer of 1995 was warmer than its 1990 counterpart. However, given the small share of energy use for space cooling, these additional requirements were inconsequential when compared to the impact of weather on space-heating energy use.

The decrease in energy intensity was the only factor working to limit the increase in residential energy use. Without the decline in energy intensity, energy use would have been 125 petajoules higher than it actually was in 1995.

Of the 125-petajoule energy intensity effect, the factorization analysis attributes 74 percent (or 93 petajoules) to the decline in space-heating energy intensity, 5 percent (or 6 petajoules) to the decline in water-heating energy intensity, 19 percent (or 24 petajoules) to the decline in appliance energy intensity and the remaining amount (2 percent, or 3 petajoules) to the decline in lighting and space cooling energy intensity. The rest of this chapter will focus on energy use trends in each of these residential end uses.

3.2.2 Factors influencing the use of energy to meet end uses in the home

Although trends are examined for each end use in this section, factorization analyses are presented only for space heating and appliances, as together, these two end uses account for 93 percent of the energy intensity effect from 1990 to 1995.

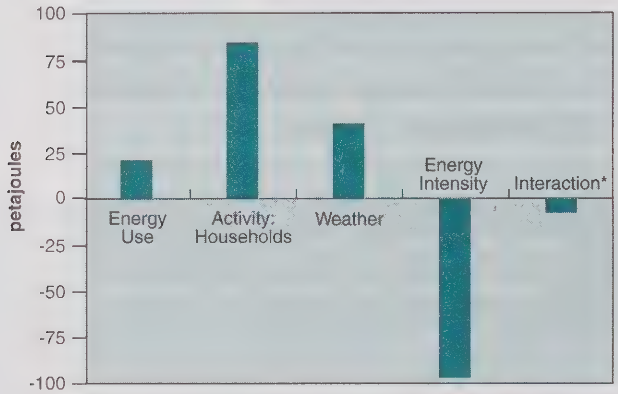
Space heating

Energy demand for space heating increased by 21 petajoules (see Figure 3.9) from 1990 to 1995. This increase can be largely attributed to the growth in activity (measured as the number of households). Had all factors affecting space-heating energy use but activity remained constant from 1990 to 1995, space-heating energy use would have increased by 83 petajoules.

Weather is clearly the most important determinant of space-heating energy requirements. The effect of weather contributed to the increase in residential energy use of 40 petajoules. This effect can be attributed to the fact that the space-heating season was colder in 1995 relative to 1990.

Figure 3.9[4] shows that the increase in space-heating energy use due to activity and weather was offset by changes in energy intensity. Had all factors affecting space-heating energy use but energy intensity remained constant from 1990 to 1995, space-heating energy use would have decreased by 95 petajoules.

Figure 3.9
Factors Influencing Growth in Residential Space-Heating Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Space-heating energy intensity is influenced by many factors including improvements in the efficiency mix of heating equipment, improvements in the thermal requirements for new and existing houses and increases in heated living area. The rest of this section reviews these factors.

The efficiency of heating equipment

Newer homes have more efficient heating systems[5] than older homes as a result of an improvement in equipment efficiencies over the last two decades. This reflects a shift in oil and natural gas heating equipment from conventional efficiency (i.e., annual fuel utilization efficiencies [AFUE] of between 60 and 65 percent) to mid-efficiency (78 to 83 percent AFUE) and high-efficiency (90 percent or more).

Indeed, ten years ago conventional-efficiency units dominated the market for oil furnaces. However, according to the *Survey of Canadian New Household Equipment Purchases*[6] (see sidebar below), only 4 percent of respondents who purchased a new oil furnace in 1994 bought a conventional unit. Similarly, in 1995, only 1 percent of new oil furnace buyers chose the conventional option.

SURVEY OF CANADIAN NEW HOUSEHOLD EQUIPMENT PURCHASES

Up to now, NRCan has sponsored two surveys on the characteristics of energy-consuming household equipment purchased by Canadian households in 1994 and 1995. These surveys, conducted by Market Facts of Canada Ltd. as a supplement to their *Household Equipment Survey*, gather information on newly purchased residential appliances including major "white" goods (refrigerators, freezers, clothes washers, clothes dryers, dishwashers and ranges), heat pumps, and room and central air conditioners. Information includes ownership, date of acquisition, brand name and various appliance features.

The surveys were conducted nationally. Approximately 9000 households filled out and returned the questionnaires. NRCan does not intend to repeat this survey on an annual basis, as initially planned, since the findings of the two surveys showed that there were stable buying patterns regarding both the frequency of purchase of new appliances and their features.

The results of these two surveys are reported in a document titled *Survey of Canadian New Household Equipment Purchases, 1994 and 1995.* A second report presents the energy consumption and characteristics evolution of household energy-consuming equipment by comparing the results of the 1994 and 1995 surveys with the 1993 Survey of Household Energy Use, this report is titled *The Household Equipment of Canadians: Features of the 1993 Stock and the 1994 and 1995 Purchases.*

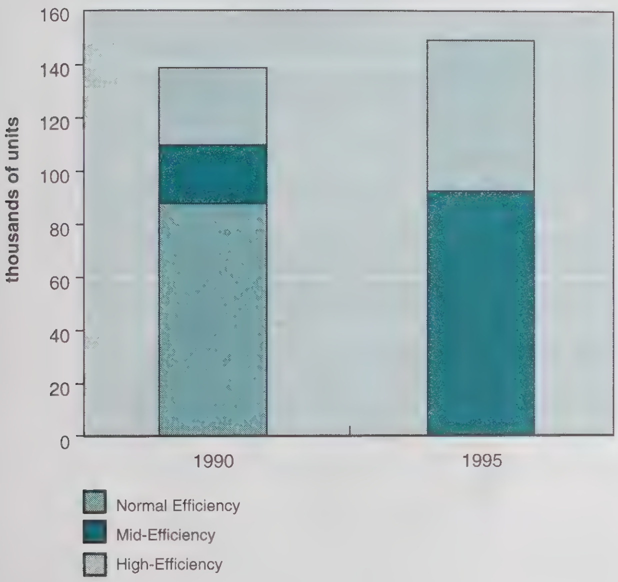
4 At this detailed level of end-use disaggregation, there is insufficient information available to define a structural effect. In this regard, structure is not addressed for space heating.

5 Fuel-fired furnace efficiency is determined from standardized testing procedures that simulate seasonal performance. This measure of efficiency is the Annual Fuel Utilization Efficiency (AFUE), which is expressed as a percent. Electric resistance heating equipment is assumed to have an AFUE of 100%.

6 Supplement to Market Facts' 1994 and 1995 *New Household Equipment Survey*, conducted for Natural Resources Canada by Market Facts of Canada Ltd. under the National Energy Use Database Initiative.

As shown in Figure 3.10, there is also a trend toward more efficient units in the Canadian shipments of natural gas furnaces.[7] In 1990, 63 percent of natural gas furnace shipments had a conventional level of efficiency. Of the natural gas furnaces that were shipped in 1995, 62 percent were mid-efficiency units and 38 percent were high-efficiency units.

Figure 3.10
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1995 (thousands of units)



THE EFFECT OF CAPITAL STOCK TURNOVER

Only a fraction of today's capital stock of heating equipment comprises products that have entered the market since 1990. The majority of the stock is composed of products that have penetrated the market over the last two decades. It will take several years for recent energy efficiency improvements to significantly affect the average efficiency of the stock of appliances/equipment used in Canadian households.

In the case of household appliances, for example, the results of the *1993 Survey of Household Energy Use* indicate that the average age of hot air natural gas furnaces was 12.5 years. In this regard, the decline in energy intensity observed for the period 1990 to 1995 is a reflection of the average efficiencies of appliances used in Canadian households today, most of which were acquired over the past 10 to 20 years.

The trend toward more efficient heating equipment over the last 10 to 20 years has led to an increase in the AFUE of the stock from about 64 percent in 1990 to 66 percent in 1995 for gas-heating systems and from 60 percent in 1990 to 61 percent in 1995 for oil-heating systems (see sidebar below). In fact, if the efficiency of the stock of furnaces used in Canadian households in 1995 had remained at 1990 levels, space-heating energy use would have been 14 petajoules higher in 1995 than it actually was.

Energy efficiency in new housing

The decline in space-heating energy intensity is also due to the fact that newer homes are more energy-efficient than existing homes. Results from the *1993 Survey of Household Energy Use* (SHEU)[8] (see sidebar below) indicate that homes built more recently are likely to have more efficient windows (double- and triple-panes) and will tend to have less air leakage than older houses.

SURVEY OF HOUSEHOLD ENERGY USE

The *1993 Survey of Household Energy Use* (SHEU) was the first of a series of surveys covering the residential sector sponsored by NRCan under the National Energy Use Database Initiative. The survey gathered the most comprehensive information to date on the energy characteristics of the Canadian housing stock.

The SHEU was first conducted in March 1993, and it will be repeated in October 1997. In the meantime, NRCan is carrying out small-scale annual surveys and complementary studies. The information is used to monitor trends in sales of energy-consuming appliances, characteristics of newly built houses, and retrofit activities in the Canadian housing stock (see sidebars called *Survey of Canadian New Household Equipment Purchases, Survey of Houses Built in Canada in 1994* and *Home Energy Retrofit Survey).*

The 1993 SHEU was conducted nationally by Statistics Canada for NRCan. It covered about 15 000 dwellings (houses or apartments) across Canada (excluding the Territories) and had an overall response rate of 72 percent.

The survey collected data on space- and water-heating equipment, energy-consuming appliances, lighting, and thermal envelope characteristics of Canadian dwellings. Two statistical reports of the survey results were compiled under the following titles: *Statistical Report: 1993 Survey of Household Energy Use — National Results* and *Statistical Report: 1993 Survey of Household Energy Use — Provincial Results.*

7 Canadian Gas Association, *Canadian Gas Facts 1996*, North York, Ontario, October 1996.

8 Natural Resources Canada, *1993 Survey of Household Energy Use*, Ottawa, Ontario, November 1995. Survey undertaken by Statistics Canada for NRCan under the National Energy Use Database Initiative.

The presence of double- and triple-pane windows is higher in newer houses. According to the SHEU, 89 percent of respondents living in houses built after 1982 reported having double- and triple-pane windows, compared to 57 percent for respondents with houses built between 1941 and 1960. This trend is also confirmed by the results from the 1994 *Survey of Houses Built in Canada in 1994* (SHBC)[9] (see sidebar below). According to the SHBC, over 90 percent of respondents who owned houses built in 1994 reported having at least double-pane windows.

When asked if they felt there were any air leaks or drafts in their houses, 26 percent of SHEU respondents who owned a house built before 1941 reported air leaks as opposed to only 12.4 percent for respondents owning a house built after 1982.

The increase in the share of newer, more energy-efficient housing to total housing has exerted downward pressure on space-heating energy use. Figure 3.11 shows that the proportion of newer homes (built between 1983 and 1995) increased from 16 percent in 1990 to 25 percent in 1995.

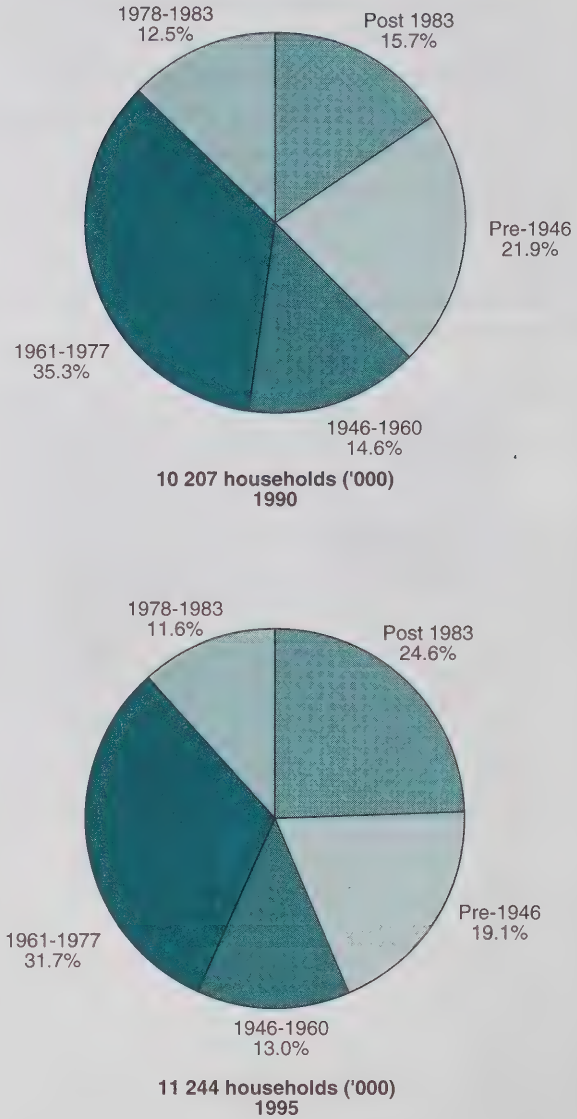
SURVEY OF HOUSES BUILT IN CANADA IN 1994

The *Survey of Houses Built in Canada in 1994* (SHBC) collects information on the energy characteristics of the thermal envelope and space-heating and -conditioning equipment in new houses. It was first conducted in 1995 by Criterion Research Corporation for NRCan.

The SHBC collected data from about 2300 households across Canada. The target population of this survey was defined as residents of homes built and completed in Canada in 1994. The survey used a mail- in/mail-back questionnaire methodology with builders validating the information when necessary. NRCan plans to repeat this survey in 1998.

The results of the SHBC are reported in the document titled *Survey of Houses Built in Canada in 1994*. Using these results and the data from the *1993 Survey of Household Energy Use*, a second report compares the energy consumption and characteristics of houses built in 1994 to the stock of houses built in 1993.

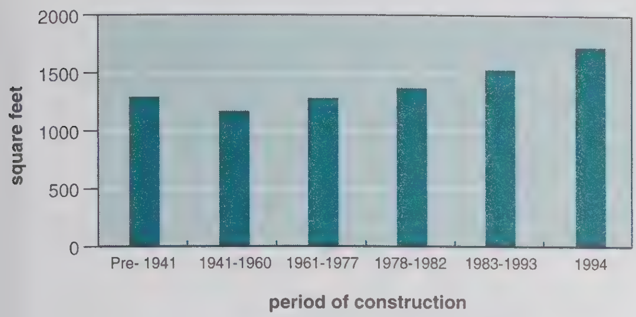
Figure 3.11
Housing Stock by Vintage, 1990 and 1995 (percent)



However, as shown in Figure 3.12, new homes are larger than homes built in the past. A house built in 1994 has an average heated living space of 1732 square feet according to the SHBC, compared to 1532 square feet for a house built between 1982 and 1993, as reported in the 1993 SHEU. In this regard, the increase in the size of new houses has led to increased heating requirements, thus offsetting some of the gains in efficiency described above.

9 The *Survey of Houses Built in Canada in 1994* was conducted for Natural Resources Canada by Market Facts under the National Energy Use Database Initiative. The survey covered about 2300 homeowners across Canada.

igure 3.12
verage Heated Living Area per Dwelling by Vintage (square feet)



Energy efficiency in existing housing

According to the results of the 1994 *Home Energy Retrofit Survey* (HERS)[10] (see sidebar below), existing homes are also becoming better insulated. Table 3.1, which presents the results of HERS, indicates that between 5 to 7 percent of homeowners performed energy retrofit improvements to either their insulation, windows or exterior doors in 1994. Furthermore, 19 percent of respondents reported that they integrated other energy-saving features in their homes (eg., low-flow shower heads, programmable thermostats, and insulation of hot water tanks and pipes).

HOME ENERGY RETROFIT SURVEY

The *Home Energy Retrofit Survey* (HERS) is a supplement to the *Homeowner Repair and Renovation Survey* (HRRS). Statistics Canada has conducted the HRRS every year since 1988. The HRRS collects expenditure information on repairs and renovations done in Canadian households the year before the survey is conducted. The HRRS is a national survey with a sample size of 40 000 dwellings and an approximate response rate of 53 percent.

At the request of NRCan, the scope of the HRRS was increased in 1995 to include the NRCan supplement. The HERS was implemented to measure the energy retrofit activities in Canadian homes in 1994. It collects information on all retrofit activities and characteristics including insulation, window and door replacements, and heating system upgrades. The HERS was also repeated for 1995.

The results of the first survey are reported in a document titled the *1994 Home Energy Retrofit Survey*. The HERS survey report for the second survey year will be available in early 1998.

About 1 percent of respondents to the 1994 HERS reported having made structural extensions to their dwellings, thereby increasing floor space. This increase in floor space, which leads to increased space-heating requirements, worked toward offsetting gains in efficiency.

Table 3.1
Retrofit Activity in Canada, 1994

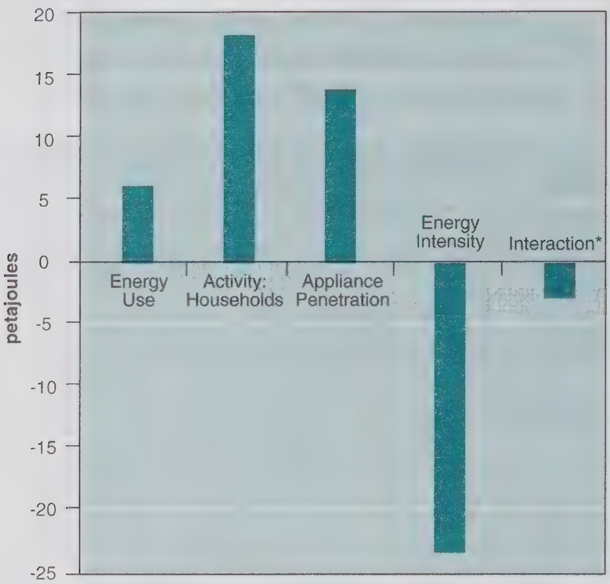
Retrofit Activity	Percentage of Dwellings
Improvements to insulation	5.0
Improvements to windows	6.9
Upgrade single to double	2.4
Upgrade double to triple	0.7
Improved caulking and weather stripping	2.1
Improvements to exterior doors	6.2
Upgrades from wood to metal	3.1
Improved caulking and weather stripping	1.6
Addition of new storm doors	1.1
Upgrades or replacement of heating equipment	2.0
Additions of other energy-saving features	18.9

Appliances

Energy used by appliances increased by 6 petajoules from 1990 to 1995. Figure 3.13 shows the factors that influenced this increase.

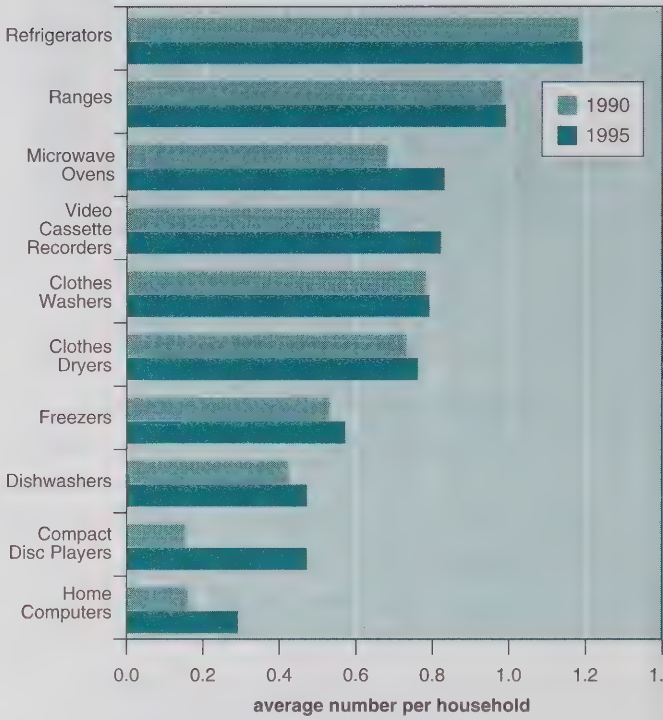
10 *The Home Energy Retrofit Survey* is a supplement to the *Homeowner Repair and Renovation Expenditure Survey in Canada*, 1994.

Figure 3.13
Factors Influencing Growth in Residential Appliance Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Figure 3.14
Penetration Rates for Household Appliances, 1990 and 1995 (average number per household)



The increase in appliance energy use can be attributed to growth of two factors. The first factor, activity (the number of households), put upward pressure on appliance energy use by about 18 petajoules. The second factor, penetration of appliances, contributed to an increase in appliance energy use by about 14 petajoules.

Figure 3.14 illustrates the penetration rates of 10 appliances for the years 1990 and 1995. The most significant increases for major appliances (refrigerators, freezers, dishwashers, clothes dryers, clothes washers and ranges) concerned dishwashers, freezers and clothes dryers. Dishwashers increased in penetration by 5 percentage points from 42 percent of households in 1990 to 47 percent in 1995, while freezers increased by 4 percentage points from 53 percent to 57 percent, and clothes dryers increased 3 percentage points from 73 percent in 1990 to 76 percent in 1995.

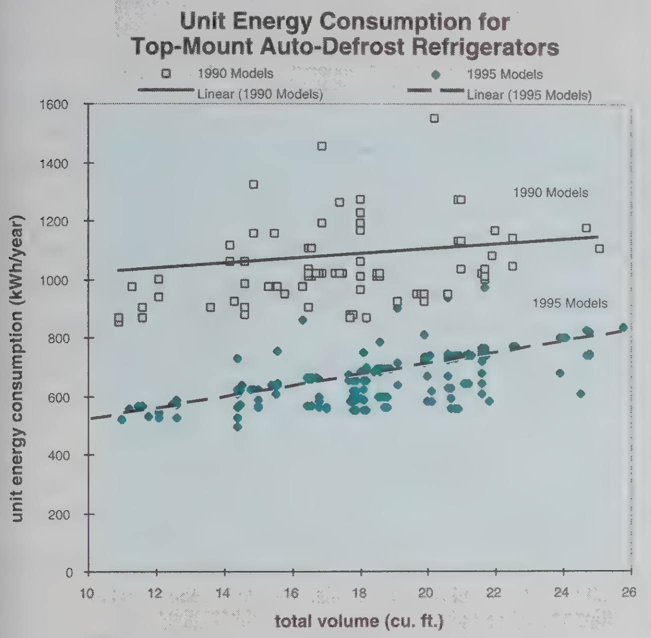
More efficient appliances

The increase in energy use associated with appliances was partially offset by substantial improvements in their energy efficiency, thus putting downward pressure on intensity. More efficient appliances have contributed to a decrease in appliance energy use by about 23 petajoules. Figure 3.15 illustrates the change in efficiencies for new, major appliances between 1990 and 1995. By 1995, the average, new refrigerator was 35 percent more efficient than its 1990 counterpart (see sideba on page 23).

Other notable energy efficiency improvements were achieved for electric clothes dryers (32 percent), dishwashers (30 percent), freezers (25 percent), and clothes washers (13 percent).

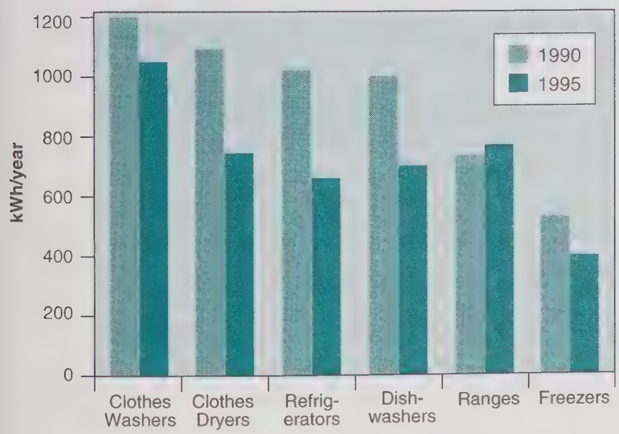
ENERGY EFFICIENCY TRENDS FOR REFRIGERATORS

An average, new automatic-defrost refrigerator with top-mounted freezer had a unit energy consumption rating of about 1020 kWh per year in 1990 and about 660 kWh per year in 1995. This represents a reduction in the unit energy consumption of these new refrigerators of about 35 percent over the period. In general, the highest unit energy consumption ratings for 1995 models were less than the lowest unit energy consumption ratings for 1990 models. At the same time, the size of these refrigerators, a factor contributing to energy consumption, increased by 16 percent. The reduction in unit energy consumption associated with the integration of more energy-efficient technologies has more than offset the increase in energy consumption associated with size.



Source: Natural Resources Canada, ***EnerGuide Database, 1990 and 1995***, Ottawa, Ontario.

Figure 3.15
Average Unit Energy Consumption of New Appliances, 1990 and 1995 (kWh per year)



Increased penetration of minor appliances

Increasing availability and marketing of "minor" appliances has exerted upward pressure on appliance energy consumption in recent years. Minor appliances include everything not included under the six major appliances, space heating, water heating, air conditioning and lighting.

Among the recent market entrants, home computers showed a large increase from 1990 to 1995 (see Figure 3.14). In 1990, only 16 percent of Canadian households had a home computer. By 1995, home computers were present in 29 percent of all households.

In 1990, only 15 percent of households had a compact disc player. By 1995, 47 percent of households had a compact disc player—the most significant increase (32 percentage points) in penetration of all appliances shown in Figure 3.14.

The saturation rate for video cassette recorders (VCRs) was about 66 percent in 1990. By 1995, that proportion had increased to over 82 percent.

There has also been rapid growth in microwave ovens. In 1990, 68 percent of Canadian households had a microwave oven. By 1995, microwave ovens were present in 83 percent of all households. Microwaves use less energy relative to conventional ovens when they are used for heating food. The net energy effect of an increase in the use of microwave ovens depends on whether they are used as a complementary appliance (i.e., defrosting or reheating of food) or a substitute for conventional ovens.

For the most part, minor appliances use much less energy on a per unit basis compared to major appliances. However, the aggregate consumption of minor appliances is not trivial. According to a recent study conducted by the Canadian Residential Energy End-Use Data

and Analysis Centre (CREEDAC),[11] these appliances account for 1300 kWh of electricity per household per year—representing more energy than that consumed by an average refrigerator used in most Canadian households.

Other residential end uses

Water heating

Water is heated for bathing (showers and baths), clothes washing, dishwashing, and sink uses. The energy used to heat water increased by approximately 8 percent from 1990 to 1995. Much of this increase can be explained by the increase in the number of households. In addition, more households now have two water-using appliances: dishwashers and clothes washers.[12] The most notable increase, shown in Figure 3.14, was in the number of households equipped with dishwashers, which increased 5 percentage points over the period.

Fuel switching was another factor contributing to the increase in water-heating energy use with the shift to gas water heaters from more technically efficient electricity-based systems.

The increase in water-heating energy use has been partially offset by efficiency improvements. As shown in Figure 3.15, new dishwashers were at least 30 percent more efficient in 1995 compared to 1990. Furthermore, improvements in the technical efficiencies of new water heaters have led to increased efficiencies of 2 to 4 percent for electric, gas and oil water heaters.

Lighting

Electricity consumption for lighting accounts for 4 percent of total residential energy use. A recent report from CREEDAC is the first to provide an estimate of the average annual amount of electricity used for lighting per Canadian household. Using data on the average number of bulbs per household collected through the 1993 SHEU, CREEDAC estimates that the average energy consumption attributed to lighting is about 1767 kWh per dwelling.

The results of the study indicate that incandescent bulbs are by far the most common source of lighting in Canadian households. The average number of incandescent bulbs per dwelling in Canada is almost 25, accounting for 93 percent of household lighting requirements. Fluorescent lighting, which averages 2.2 lamps per household, represents about 6 percent of total lighting requirements, followed by halogen lighting (0.4 lamps per household) at less than 1 percent.

Space cooling

Energy used in space cooling accounts for less than 1 percent of total residential energy use. However, air conditioners are becoming more common in Canada.

The most notable increase is for central air conditioners, which consume more energy relative to room air conditioners. The penetration rate of central air conditioners rose from 14 percent of households in 1990 to 17 percent in 1995.

11 Canadian Residential Energy End-Use Data and Analysis Centre, *Residential Electrical Energy Use Associated with Miscellaneous Appliances in Canada*, Halifax, Nova Scotia, October 1996.

CREEDAC was created under the National Energy Use Database Initiative announced by Natural Resources Canada in 1991 as part of its Efficiency and Alternative Energy Program.

12 Approximately 88 percent of the energy used by dishwashers and 92 percent of the energy used by clothes washers is used to heat the water; the remaining energy is used by motors.

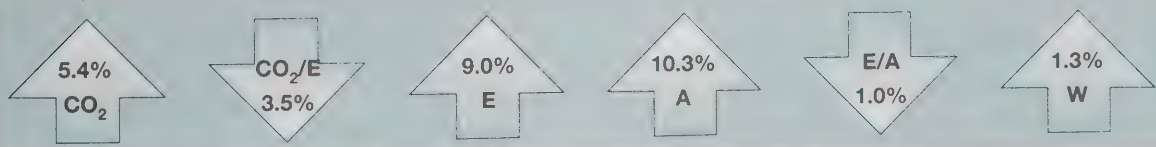
Chapter 4

Commercial Sector

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from the use of energy in the commercial sector increased by 5.4 percent from 1990 to 1995, as the impact on emissions of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity (CO_2/E) of commercial energy use decreased by 3.5 percent. In the absence of the decline in carbon dioxide intensity, emissions would have increased by 9.0 percent.
- The major cause of the rise in carbon dioxide emissions in the commercial sector was the 9.0 percent, or 77 petajoule, increase in energy use (E). In the absence of the increase in energy use, emissions would have declined by 3.5 percent. The growth in commercial sector energy use from 1990 to 1995 was largely influenced by changes in activity, the mix of activity, weather and energy intensity. The impact of these factors was the following:

- Commercial activity (A) increased by 10.3 percent. Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by almost 88 petajoules.
- The change in the distribution of floor space marginally influenced commercial energy use. Had all the other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only 3 petajoules.
- Fluctuation in climatic conditions (W) also had an upward influence on energy use. Had all the factors but weather conditions remained at their 1990 level, energy use would have increased 12 petajoules.
- Energy intensity (E/A) was slightly lower in 1995 compared to 1990. Had only energy intensity fluctuated over the period of analysis, energy use would have decreased by 23 petajoules.



The commercial sector is defined to include activity related to trade, finance, real estate services, public administration, education and commercial services (including tourism). In this sector, energy is mainly used to provide space and water heating; space cooling; lighting motive power for services such as pumping and ventilation in buildings; and street lighting.[1]

1 Of the analysis presented in this chapter, any distributions of energy use by building type and all discussions of the energy use factorization analysis exclude street-lighting energy use. This component of commercial energy use amounts to 10 petajoules in 1990 and 8 petajoules in 1995.

As noted in Chapter 1, it is recognized that, among the four sectors studied in detail in this report, energy use data problems are most limiting in the commercial sector. For this reason, the analysis presented in this chapter is less elaborate and detailed than that presented in other sector chapters. It is hoped that suitable data on floor space and on the characteristics of commercial buildings can be made available through the National Energy Use Database in the future. A recent project studying the feasibility of such a data collection exercise shows promise. (See sidebar on the right).

Figure 4.1 presents the distribution of commercial energy use and activity by building type for 1995. About three-quarters of commercial energy use and floor space is accounted for by retail, office, educational and health buildings. In general, the share of energy use accounted for by individual building types is comparable to their share of activity (floor space). Only in three cases, health facilities, hotel/restaurant and warehouses, is the share of energy use notably different from the share of floor space. In the first two of these building types, the share of energy use is larger than the share of floor space, reflecting the energy-intensive activity that takes place in these sectors. In warehouses the opposite is true, as basic space requirements are a primary priority and energy requirements to condition the space are secondary.

COMMERCIAL SECTOR SURVEY FEASIBILITY STUDY

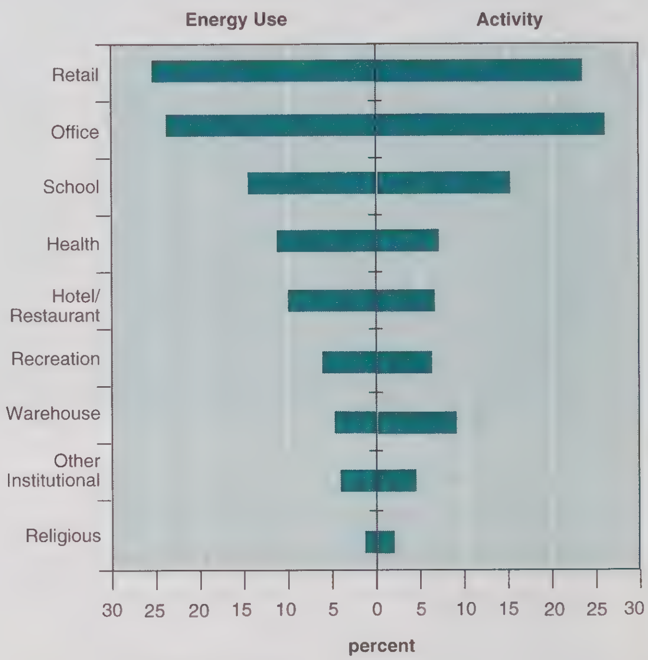
The Canadian Commercial Energy End-Use Data and Analysis Centre (CCEEDAC), funded by NRCan and established at McMaster University, Hamilton, Ontario, conducted a study discussing design considerations for a survey of commercial building energy use in Canada. The report titled *Commercial Sector Energy End-Use Data in Canada: Recommendations for a National Data Collection Strategy* provided an overview of the requirements for a survey of Canadian commercial buildings and included a number of recommendations.

Following these recommendations, a market research consulting firm was mandated to prepare a detailed study on the feasibility of implementing a data collection strategy for the Canadian commercial sector. The study was commissioned by NRCan under its National Energy Use Database Initiative.

The study, which reviews the current state of data on commercial energy use and its major determinants (floor space, characteristics of buildings and energy-using equipment) and describes and recommends possible approaches to data collection, was discussed at a workshop coordinated by CCEEDAC. At this workshop, experts in the field of energy use analysis and data development were gathered to review and comment on the recommendations of the study.

NRCan is currently developing an action plan for data collection in the commercial sector based on the information presented in the feasibility study.

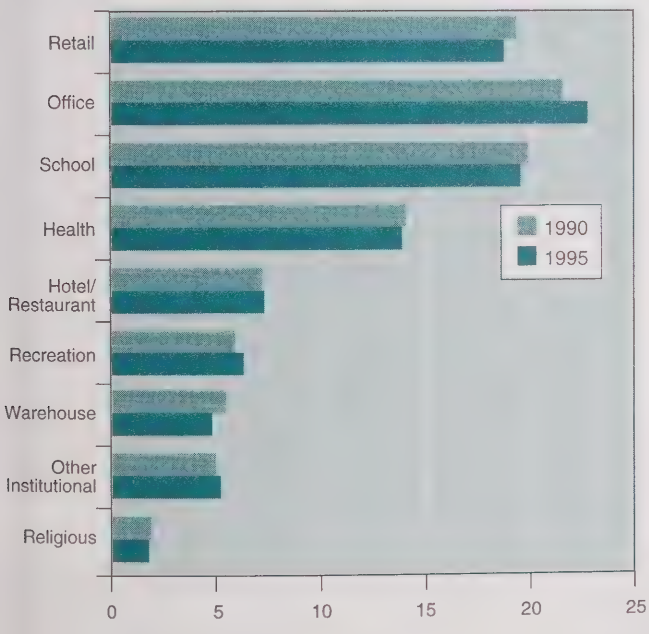
Figure 4.1
Distribution of Commercial Energy Use and Activity by Building Type,* 1995 (percent)



* Excluding street lighting

Figure 4.2 presents the contribution of each building type to total commercial carbon dioxide emissions in 1990 and 1995.[2] The same four building types noted above as accounting for three-quarters of energy use also account for a similar share of emissions. Most of the increase in carbon dioxide emissions (1.4 megatonnes) between 1990 and 1995, however, did not originate from the use of energy in these four building types. Of these four, only office buildings, with an 11 percent increase in emissions over the period, ranked as one of the top three contributors to the increase in emissions. The two building types that contributed most to the 1990 to 1995 increase in commercial sector emissions were recreational buildings (+13 percent) and other institutional buildings (+10 percent).

Figure 4.2
Commercial Carbon Dioxide Emissions by Building Type,* 1990 and 1995 (percent)



* Excluding street lighting

Figure 4.3 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows two slight downturns in 1991 and 1994. The first of these downturns can be directly attributed to a decline in the carbon dioxide intensity of commercial energy use in 1991. The 1994 downturn in emissions can be attributed to downturns in both energy use and carbon dioxide intensity in that year. The 1994 downturn in energy use was the only divergence in the continuous upward trend in energy use over the period.

Figure 4.3
Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

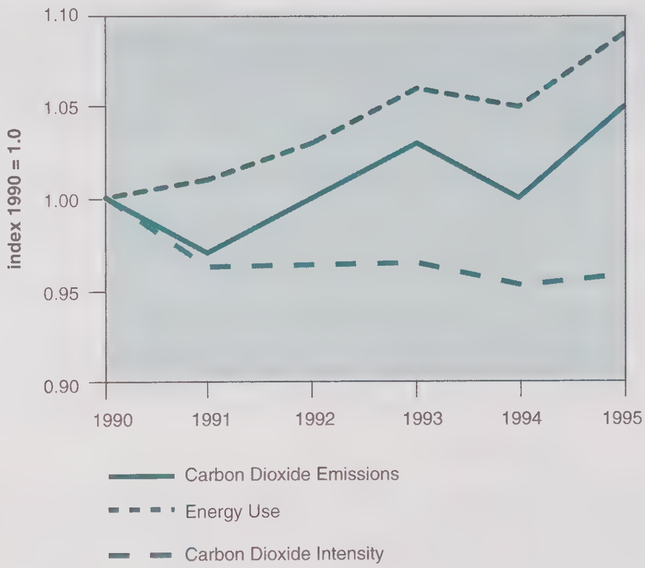


Figure 4.4 shows the growth in carbon dioxide emissions, energy use and the carbon dioxide intensity of energy use from 1990 to 1995 in the commercial sector. Emissions increased by 5.4 percent (an average annual increase of 1.0 percent), from 26.7 megatonnes in 1990 to 28.1 megatonnes in 1995. This increase in emissions was largely a result of significant

2 The definition of commercial energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences energy-related carbon dioxide emissions from the commercial sector in this report are higher than Environment Canada's by 0.7 megatonnes in 1990 and lower by 1.7 megatonnes in 1995. See Appendix D for documentation of differences.

Note also that in this report the commercial sector combines the commercial and public administration sectors, which are defined separately in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*.

growth in energy use (9.0 percent), which was partially offset by a 3.5 percent decline in the carbon dioxide intensity of energy use.

Figure 4.4
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

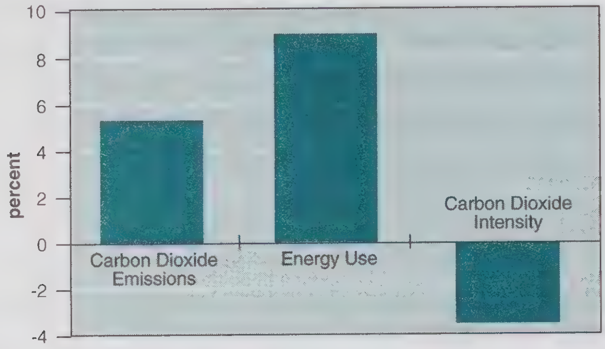
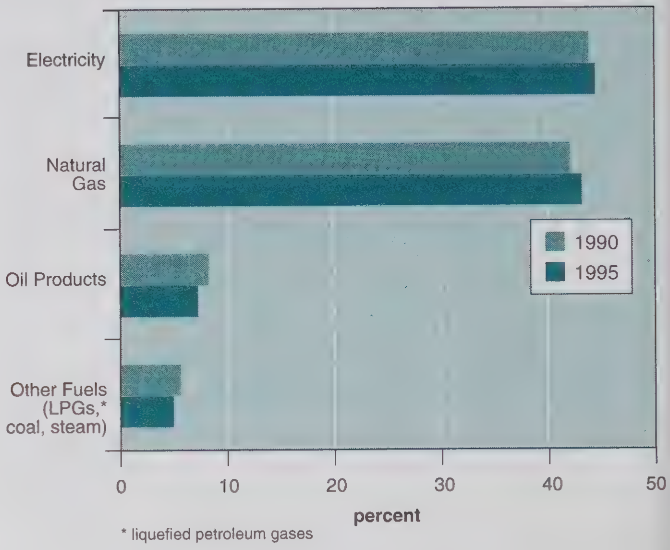


Figure 4.5
Commercial Energy Fuel Shares, 1990 and 1995 (percent)



4.1 Trend in the Carbon Dioxide Intensity of Commercial Energy Use

The reduction in the carbon dioxide intensity of energy use offset almost 40 percent of the impact on emissions of rising energy requirements. In the absence of the change in the carbon dioxide intensity of energy use, emissions would have increased by 9.0 percent, or an additional 1 megatonne over 1995 emissions.

The decline in the carbon dioxide intensity was due to a shift away from oil products and liquid petroleum gases in favour of electricity and natural gas. The market share for electricity increased by 0.6 percentage points over the five-year period beginning in 1990, reaching 45 percent of commercial energy use in 1995. The market share for oil products decreased marginally from 8 percent in 1990 to 7 percent in 1995. Most of the decrease in oil share was captured by natural gas, which increased its share by 1 percentage point from 1990 to 1995. Figure 4.5 shows the shares of fuels used to meet commercial sector needs in 1990 and 1995.

Much of the increase in the share of electricity can be attributed to the increasing penetration of space-cooling systems and office equipment (see sidebar below). During the late 1970s and early 1980s, personal computers were available only in limited numbers. Today, most office work stations are computerized. This was achieved in part by the steady increase in annual sales of microcomputers and associated peripheral equipment. Since approximately three-quarters of microcomputers are sold to educational institutions, business and government, most of the added electricity consumption from the use of this equipment is reflected in the commercial sector. However, this trend was offset somewhat by the incorporation of power management systems that automatically transfer equipment to a low power state during idling periods.

DID YOU KNOW THAT . . .

Over the last five years, the annual sales of desktop computers increased by about 81% to 1.2 million units, laptop computer sales increased by 147% to over 220 000 units per year, sales of fax machines increased by 89% to 260 000 units and laser printers sales increased by 179% to 290 000 units sold annually.

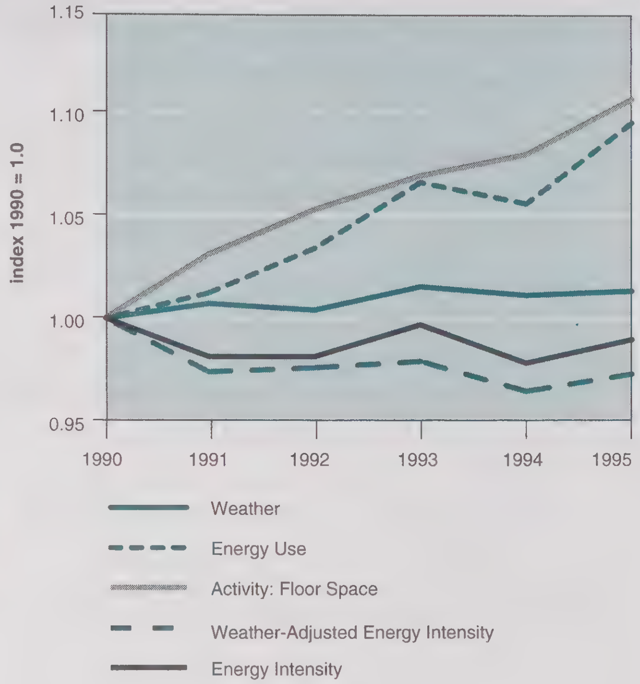
The changes in the shares of natural gas and oil are the result of increased use of gas in space- and water-heating applications as it was substituted for oil and electricity due to lower prices and greater availability. Over the 1990 to 1995 period, increases in commercial sector sales of natural gas in Quebec, Ontario and British Columbia ranged from 9 to 14 percent. The Federal Infrastructure Program facilitated two of the major gas distributors to expand their distribution network. These investment projects ended in 1995 and resulted in an increase in the natural gas consumer base of almost 7000 new consumers (mostly commercial and residential).[3]

4.2 Evolution of Commercial Energy Use and its Major Determinants

Rising commercial energy use from 1990 to 1995 had a strong influence on the growth in emissions from this sector. In the absence of the increase in energy use, emissions from the commercial sector would have decreased by 3.5 percent.

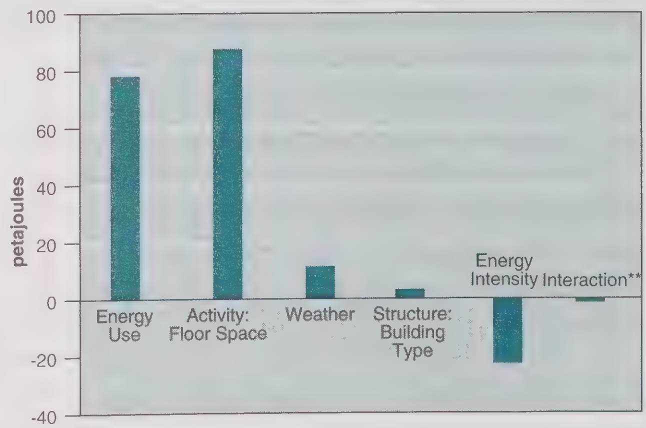
Figure 4.6 shows the trends in total commercial energy use, energy intensity, weather and activity from 1990 to 1995. Energy intensity is also presented on a weather-adjusted basis. Over this period, energy use increased by 9.0 percent (or an average annual rate of 1.7 percent), from 864 petajoules in 1990 to 942 petajoules in 1995, while activity increased by 10.3 percent (an average annual growth rate of 2.0 percent) and energy intensity declined by 1.0 percent (an average annual decline of 0.2 percent). In general, the trend in energy use was moulded by the continuous, gradual growth in activity.

Figure 4.6
Commercial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



As shown in Figure 4.7, the results of the factorization analysis attribute most of the 77-petajoule increase in energy use from 1990 to 1995 to growth in activity; changes in the mix of activity in building types, weather and energy intensity had a marginal influence on changes in energy use.

Figure 4.7
Factors Influencing Growth in Commercial Energy Use,* 1990–1995 (petajoules)



* Excluding street lighting
** For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

3 Natural Resources Canada, *Canadian Natural Gas Overview*, Ottawa, Ontario, September 1995 and August 1996.

The factorization results for the commercial sector for the period 1990 to 1995 can be summarized as follows:

- Commercial activity increased by 10.3 percent. Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by almost 88 petajoules.
- The change in the distribution of floor space by building type marginally influenced commercial energy use. Had all other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only 3 petajoules.
- Fluctuation in climatic conditions also had an upward influence on energy use. Had all the factors but weather conditions remained at their 1990 level, energy use would have increased 12 petajoules.
- Energy intensity was slightly lower in 1995 compared to 1990. Had only energy intensity fluctuated over the period of analysis, energy use would have decreased by 23 petajoules.

The next four subsections will describe some of the factors underlying the activity, structure, weather and energy intensity effects calculated for the commercial sector.

4.2.1 The influence of growth in commercial activity – the activity effect

As noted above, growth in commercial sector activity was the factor that exerted the greatest influence on commercial energy use over the first five years of the nineties. Activity alone had an upward influence on energy use of 88 petajoules.

From 1990 to 1995, oversupply of commercial space, coupled with the effect of the recession, led to a slowdown in construction activity. Consequently, commercial floor space increased on average by 2.0 percent per year over the 1990 to 1995 period after experiencing an average growth of 4.8 percent per year over the 1985 to 1990 period.

A significant amount of new office space was added to the stock in 1990 and 1991. A number of major projects were conceived in the late 1980s, and it was not until the early 1990s that these new facilities were completed. The combination of additional floor space reaching the market, when economic growth was turning for the worst, created an oversupply of office and retail space. As a result, investment in these industries in 1995 was roughly 30 percent lower than in 1990. For example, 13 million square metres of office space were added to the Toronto Census Metropolitan Area during the 1980s as compared to 0.5 million during the first half of the 1990s.[4] Further, in 1993, the value of commercial sector building permits fell to less than half of its 1989 level.[5]

Tough economic conditions also affected the accommodation sector. Over the last five years, expenditures in the business and personal service industries have been hurt by weak consumer spending and declining real disposable income, which dampened activity in the tourism and hospitality industries.

Despite fiscal restraint in the public sector, government spending on buildings was roughly 30 percent higher in 1995 than in 1990. Education and health service industries also played a major role in public sector expenditures. Over the 1990 to 1995 period, additions to floor space in schools, hospitals and other related facilities as well as in museums, offices, libraries and other institutional buildings were surprisingly robust.

4 Royal LePage, *Office Leasing Market Report*, July 11, 1996.

5 Statistics Canada, *Building Permits*, various issues, (Cat. 64-203), Annual, Ottawa, Ontario.

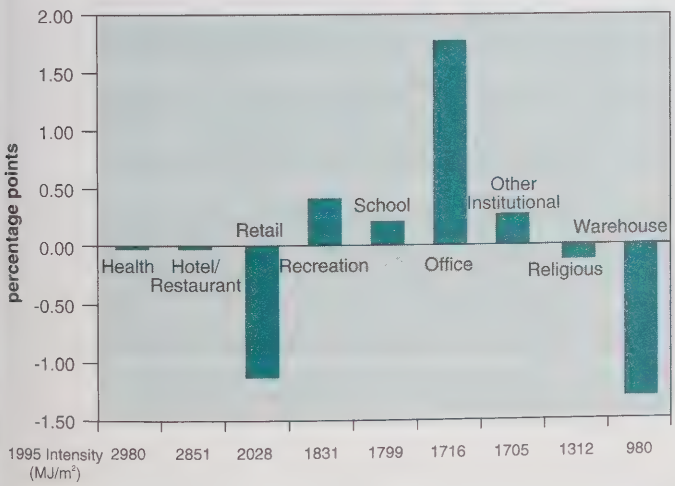
4.2.2 The influence of shifts in the mix of building types – the structure effect

About 3 petajoules of the change in total commercial energy use over the 1990 to 1995 period is associated with changes in the mix of floor area by building type. As shown in Figure 4.8, the small structure effect is the result of many small shifts in the shares of a number of building types.

The largest downward fluctuations in shares of floor space occurred in retail buildings and warehouses, two building types with largely different energy intensities. The average energy intensity of retail buildings is more than twice as large as that of warehouses.

The largest increase in the share of floor space for a given building type occurred in office buildings. This upward effect on energy use was further enhanced by an upward shift in the shares of floor space accounted for by recreational buildings, schools, and other institutional buildings. On the whole, these two sets of offsetting fluctuations had very little impact of energy use.

Figure 4.8
Changes in Building Type Shares of Commercial Activity, 1990–1995 (percentage points)



4.2.3 The influence of fluctuations in climatic conditions – the weather effect

Heating degree-days were 7 percent higher in 1995 compared to 1990 as a result of a relatively colder heating season in 1995. This contributed to an increase in space-heating requirements.

Cooling degree-days were 9 percent higher in 1995 as compared to 1990, as a result of a relatively warmer cooling season in 1995. This led to an increase in space-cooling requirements. The combination of both weather effects contributed to a 12-petajoule increase in commercial energy demand.

It should be noted, however, that when compared to the 1951–1980 average, both 1990 and 1995 were warmer than the average. In 1990, heating and cooling degree-days were 8 percent and 6 percent warmer than the average, respectively. As for 1995, they were 2 percent and 14 percent warmer, respectively.

4.2.4 The influence of variations in the intensity of commercial energy use – the intensity effect

The decrease in energy intensity from 1990 to 1995 was the only factor mitigating the increase in energy use over the period. Changes in the energy intensity of a given building type are influenced by, among other factors, changes in the energy efficiency of the buildings themselves and the equipment they house, the density of occupation of the buildings and the behaviour of the occupants. The rest of this section discusses recent developments in these areas. It is important to remember, as we begin this discussion, that it is more difficult in this sector compared to others to present definitive analysis of a detailed nature that is directly related to the aggregate results presented above because of the paucity of market information on commercial facilities.

Building and equipment energy efficiency

Space heating

Space-heating energy requirements are affected by the efficiency of the building itself —i.e., by the characteristics of the building envelope—and by the efficiency of space-heating equipment.

The efficiency of boilers and furnaces has increased considerably over the last decade. In the early eighties, typical oil- and gas-heated buildings were equipped with boilers and furnaces with seasonal efficiencies of about 60 percent. With improvements, such as the addition of high-efficiency burners, space-heating energy efficiency has increased by up to 10 percent. Today, new mid- and high-efficiency boilers have seasonal efficiencies of about 80 percent.

The improvement in the energy efficiency of boilers and furnaces has led to a significant decrease in heating energy intensities. A recent study in British Columbia found space-heating energy intensities to be 66 percent lower in new office buildings relative to existing office buildings.[6]

Lighting[7]

Fluorescent lighting accounts for about 70 percent of the energy used to light office buildings. Energy required for this type of lighting has decreased as a result of improvements to conventional fluorescent lighting systems and their increased penetration.

Standard fluorescent-lighting systems comprise two fluorescent tubes and one standard core-coil electromagnetic ballast. The energy efficiency of standard fluorescent-lighting systems has gradually improved since 1990 as a result of improvements to ballasts and lamps.

Better material in electromagnetic ballasts and the recent introduction of electronic ballasts have reduced ballast energy consumption in these systems by 50 to 75 percent. Almost absent from the market in the mid-80s, electronic ballasts accounted for 14 percent of all ballasts shipped and manufactured by the United States in 1992. Most of the ballasts sold in Canada come from the United States.

Despite a 30 percent reduction in the sale price of electronic ballasts, market penetration has been slow due to lower electricity rates, less incentive programs and the scarcity of 347-volt ballasts, which is the standard voltage used in most Canadian commercial buildings.[8]

In 1993, standard fluorescent lamps accounted for 67 percent of lamp sales, as they continued to dominate the existing market. In applications related to new buildings, however, there is a clear trend toward the installation of more energy-efficient lighting systems (particularly T-8 systems).[9] These systems are estimated to account for 75 to 95 percent of sales for installation in new buildings.

Motors

Electric motors are mainly used to drive fans, pumps and compressors found in heating, cooling and ventilation systems. They are also used to drive other types of equipment such as elevators, escalators or garage door openers.

Over the last few years, motor energy efficiency has been improved by optimizing its design and using higher quality material and improved production processes. These new techniques

6 *Achievable Conservation Potential Through Technological and Operational Change*, SRC Report No. 7933-R4, prepared for Conservation Potential Review Project Collaborative Committee, Vancouver, British Columbia, February 2, 1994.

7 Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

8 Canadian Electricity Association, *Technology Profile Summary. TP2: Electronic Ballasts*, August 1994.

9 Canadian Electricity Association, *Technology Profile Summary. TP14: Fluorescent Lamps, Linear T-12, T-10, T-8 Lamps*, August 1994.

reduce electrical losses and improve energy consumption. Depending on size, energy-efficient motors are now 2 to 10 percent more efficient than standard motors. It is estimated that more than 50 percent of new sales and 5 percent of the existing motor stock are composed of energy-efficient motors.[10]

Fans

Fans are used to move air for the provision of heating, ventilation, air conditioning and humidification/dehumidification services. While care has been given to ambient air quality, fan energy consumption has been reduced by varying the volume of air it handles.

Depending on the accessories used, energy-efficient fan systems can provide energy savings of 12 to 30 percent over main ventilation and air conditioning. Further, the reduction in air volume also saves energy used by other systems in the building. For example, boilers can be started and stopped earlier when volume reduction is applied to the heating, ventilation and air conditioning systems. A study conducted by the Canadian Electrical Association in 1995 estimated that the use of variable volume fans in large commercial buildings can save up to 2 to 5 percent of total building energy use.

Recently, variable volume fan technologies have penetrated the market. It is estimated that 80 percent of new construction and 30 percent of existing, mechanically ventilated buildings use such fan systems.[11]

Building occupancy rates

Variations in occupancy rates (occupants per floor area) also affect energy intensity. The higher the occupancy rate of a given building, the higher its energy requirements and energy intensity.

Over the last five years, the number of occupants per square metre fell by an average of 2.8 percent per year. This was the result of two offsetting trends: high building vacancy rates and space rationalization.

Due to slow employment growth and oversupply of commercial space, the national vacancy rate for office buildings reached 16 percent in 1992, with levels over 20 percent reported in a number of major centres including Calgary. Toronto, where vacancies were as low as 3.7 percent in the 1980s, reached a vacancy rate of 25.6 percent in 1992. Downtown Vancouver reached a vacancy rate of 15.9 percent in 1993.[12] The trend in occupancy rates kept energy use lower than it would otherwise have been.

10 Canadian Electricity Association, *Technology Profile Summary. TP10: AC Induction Motors*, August 1994.

11 Canadian Electricity Association, *Technology Profile Summary. TP4: Commercial and Industrial Fans*, October 1995.

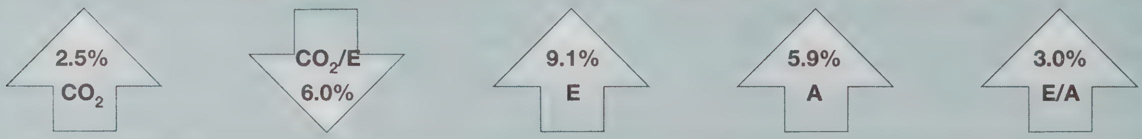
12 *Macleans*, November 1, 1993; *Calgary Herald*, July 10, 1993; *Toronto Star*, January 12, 1993; *Vancouver Sun*, February 24, 1993.

Chapter 5

Industrial Sector

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from the use of energy in the industrial sector increased by 2.5 percent from 1990 to 1995, as the impact on emissions of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity of industrial energy use (CO_2/E) decreased by 6.0 percent, as industry moved toward a greater use of fuels with a lower carbon content. In the absence of the decline in carbon dioxide intensity, emissions would have increased by 9.1 percent.
- The major cause of the rise in carbon dioxide emissions in the industrial sector was the 9.1 percent, or 241 petajoule, increase in energy use (E). In the absence of the increase in energy use, emissions would have declined by 6.0 percent.
- The growth in industrial sector energy use was largely influenced by changes in industrial activity, the mix of activity by industry and energy intensity. The impact of these three factors was the following:
  - Industrial sector activity (A) increased by 5.9 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 157 petajoules.
  - The change in the mix of activity toward more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 68 petajoules.
  - There was a slight increase in energy intensity (E/A) from 1990 to 1995. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have increased by 11 petajoules.



The industrial sector includes all manufacturing industries, as well as forestry, construction and mining.[1] In this sector, energy is used in industrial processes to produce heat, generate steam or as a source of motive power. Examples of specific process technologies used in the industrial sector are electric-arc furnaces, pulp digesters and aluminum smelters.

1 Another important set of industrial energy use data used in Canada is developed by the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) at Simon Fraser University for the Canadian Industry Program for Energy Conservation (CIPEC). These data are reported in *Energy Intensity Indicators for Canadian Industry: 1990-1995*. CIPEC uses these data to track its progress. While the energy use data found in the CIPEC database are developed using similar sources, as this report, for a number of industries, the definition of industry boundaries used in the CIPEC database is different than the one used in this report. For this reason, some of the trends described here are different than reported in the CIPEC data.

Most of this chapter will focus on the six largest energy-consuming industries: pulp and paper, mining, petroleum refining, iron and steel, chemicals, and smelting and refining. As shown in Figure 5.1, together these six industries accounted for less than 30 percent of total industrial activity [2] (see sidebar on the right), but used 77 percent of total industrial energy (see sidebar below) in 1995.

MEASURES OF INDUSTRIAL ENERGY USE: THE INDUSTRIAL CONSUMERS OF ENERGY SURVEY

The energy use data presented in this report are taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD). This source is used because it is Canada's official energy supply and demand balance, and it forms the basis for Canada's inventory of greenhouse gas emissions.

Traditionally, the QRESD data were estimated from a suite of Statistics Canada surveys of energy distributors and end users. Up to 1993, most of the data were estimated from supply sources. As of 1994, the source of end-use data for the QRESD, the *Industrial Consumers of Energy survey (ICE)*, has been greatly expanded. The 1995 survey included some 2000 respondents, up from a total of 230 respondents in 1993. As a result of expanding the *ICE Survey*, data are now available (for 1995) for 24 industries rather than the previous 10. Environment Canada is now using these data to produce supplementary emission estimate for these industries.

As more information from the ICE survey becomes available, efforts will be aimed at integrating the greater sectoral disaggregation into this analysis. This should allow an increased understanding of the influence of sector structure and intensity on energy use. In the end, Canada's industrial energy use tracking system will be greatly improved.

The expansion of the *ICE Survey* is a data development initiative entirely funded by Natural Resources Canada's National Energy Use Database Initiative. The design of the survey was done in cooperation with the Canadian Industry Program for Energy Conservation, Environment Canada, the Canadian Industrial Energy End-Use Data and Analysis Centre and Statistics Canada. The survey is conducted by Statistics Canada.

MEASURES OF INDUSTRIAL ACTIVITY: PHYSICAL OR ECONOMIC?

Since the first issue of *Energy Efficiency Trends*, published in April 1996, the possibility of using other measures of industrial activity in the analysis of energy use and emissions trends has been investigated. While this report still uses Gross Domestic Product as an indicator of industrial activity, the factorization analysis was also done using Gross Output, an alternative measure of economic output.

The advantages and disadvantages of using either Gross Domestic Product or Gross Output as a measure of activity in the industrial sector are many. An analysis of these pros and cons leads to the conclusion that, while Gross Output might be a favoured activity indicator on a subsectoral level, some of these qualities are lost in aggregation because of the double-counting of some outputs. Gross Domestic Product is a better aggregate measure, but since it reflects value added, its variability, particularly on a subsectoral basis, can overemphasize cyclical movements. This variability is directly reflected in energy intensity.

For this report, we chose to continue using Gross Domestic Product as a measure of activity because the analysis is done at a relatively aggregate level of detail, and at this level, confidence in Gross Domestic Product is greater. In addition, Gross Domestic Product still remains the activity indicator of choice at the international level. Any comments on the approach taken in this report and on ways of improving it are welcome.

As noted in the initial report, for other purposes, such as the tracking of sector-specific energy-efficiency progress in industry, the use of physical output measures is more suitable. This is the approach chosen by the Canadian Industry Program for Energy Conservation (CIPEC), whose main objective is to promote energy efficiency in the manufacturing and mining sectors and track progress for each participating industrial sector. To do this, CIPEC uses a combination of measures of economic and physical output depending on the sector. Physical output measures are always the first choice, and economic output measures are only adopted in special cases, example, where, for an industry's products are too heterogeneous and numerous to allow the choice of one representative physical output measure for that industry.

In the future, while the demands of the analysis presented in this report might continue to point to an economic indicator of activity, efforts will be made to present, in the accompanying database, alternative indicators and the results of the analysis undertaken with these indicators.

2 Industrial activity is measured as gross domestic product in 1986 dollars.

Figure 5.1
Distribution of Industrial Energy Use and Activity by Industry, 1995 (percent)

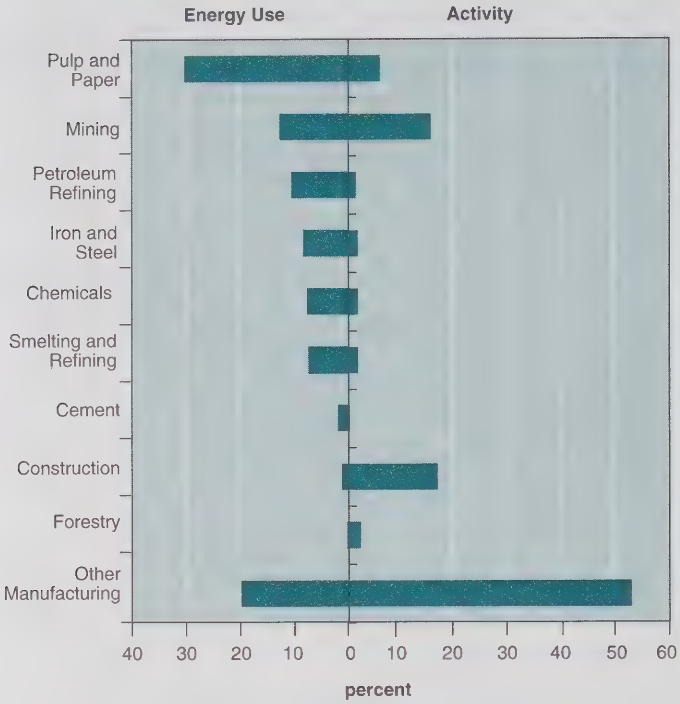


Figure 5.2
Industrial Carbon Dioxide Emissions by Industry, 1990 and 1995 (percent)

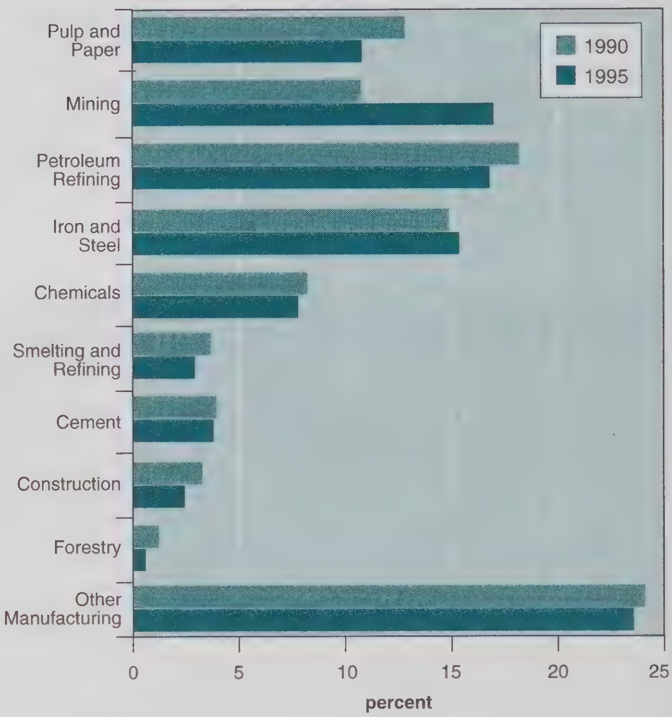


Figure 5.2 shows the distribution of carbon dioxide emissions by industry in 1990 and 1995.[3] The six largest energy-consuming industries account for the bulk (70 percent) of carbon dioxide emissions. Figure 5.2 also reveals that the share of emissions accounted for by the six largest energy-consuming industries increased by 2 percentage points over the period, mainly as a result of the significant growth in emissions from the use of energy in mining. The growth in emissions from mining is directly related to significant growth in energy use in this industry. This is explained in section 5.2.

Figure 5.3 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows that only in 1995 were emissions higher than in 1990. In general, energy use increased after the 1992 recession, but emissions growth did not follow as it was pulled down by a particularly sharp decline in carbon dioxide intensity in 1993.

3 The definition of industrial energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the industrial sector in this report are higher than Environment Canada's by 21.1 megatonnes in 1990 and 21.8 megatonnes in 1995. See Appendix D for documentation of differences.

Table 5.1
Summary of Trends in Emissions, Energy Use and CO_2 Intensity of Energy Use in the Industrial Sector for the Six Largest Energy-Consuming Industries, 1990–1995 (percent change)

	Emissions	CO_2 Intensity of Energy Use	Energy Use
Total Industrial	+2.5	-6.0	+9.1
Pulp and Paper	-13.6	-26.4	+17.4
Mining	+62.2	+15.7	+40.2
Petroleum Refining	-5.3	+1.1	-6.4
Iron and Steel	+5.9	-3.6	+9.9
Chemicals	-2.9	+4.2	-6.8
Smelting and Refining	-18.7	-30.3	+16.7

gure 5.3
dustrial Carbon Dioxide Emissions, Energy Use and Carbon ioxide Intensity, 1990–1995 (index 1990 = 1.0)

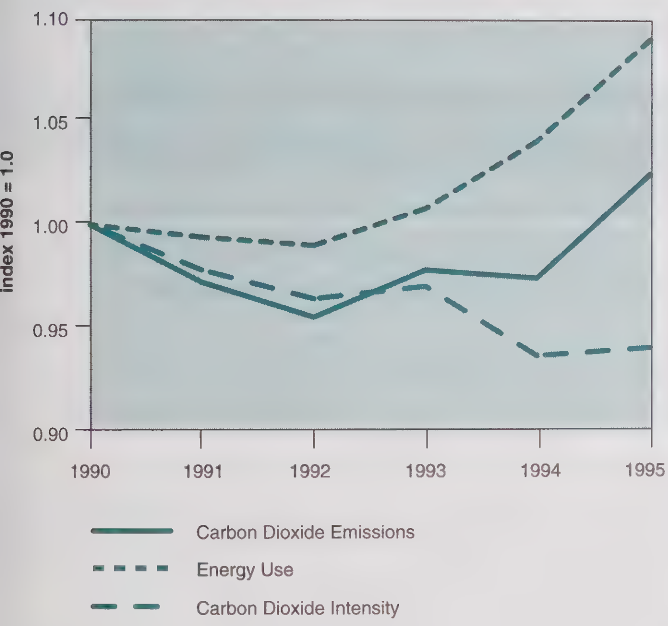


Table 5.1 summarizes the growth in carbon dioxide emissions, energy use and carbon dioxide intensity of energy use over the first five years of the nineties for the industrial sector as a whole and the six largest energy-consuming industries. Carbon dioxide emissions resulting from energy use in the industrial sector increased by 2.5 percent (an average annual increase of 0.5 percent), from 96.4 megatonnes in 1990 to 98.9 megatonnes in 1995.

Two important observations can be gleaned from the data in Table 5.1. First, both energy use and its carbon dioxide intensity had a major influence on carbon dioxide emissions; however, these were offsetting influences, with carbon dioxide intensity mitigating the rise in emissions resulting from increased energy use. Second, growth rates for carbon dioxide emissions vary widely across industries. Emissions from the mining industry increased by more than 62 percent from 1990 to 1995, while emissions from smelting and refining declined by almost 19 percent.

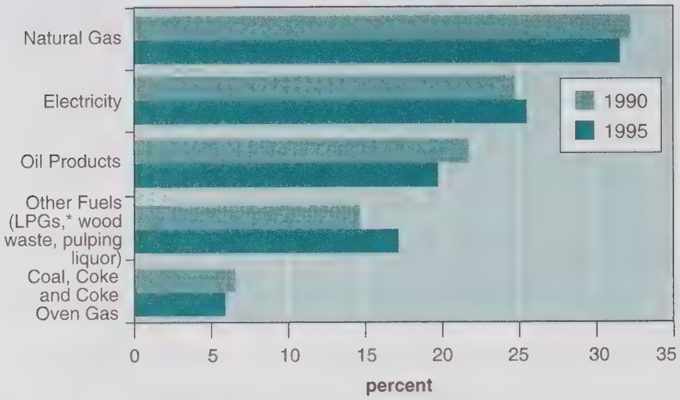
The next two sections will focus on explaining trends in the carbon dioxide intensity of industrial energy use (section 5.1) and the evolution of energy use (section 5.2), the two major determinants of change in emissions.

5.1 Trend in the Carbon Dioxide Intensity of Industrial Energy Use

The 6.0 percent decline in the carbon dioxide intensity of industrial energy use from 1990 to 1995 (see Table 5.1) played a major role in limiting growth in carbon dioxide emissions to 2.5 percent. In the absence of this decline in carbon dioxide intensity, emissions would have increased by 9.1 percent, or an additional 6 megatonnes over emissions in 1995.

The downward trend in carbon dioxide intensity was mainly due to fuel shifting from oil products (down 2.0 percentage points) to less carbon dioxide-intensive "other fuels"[4] (up 2.5 percentage points) and electricity[5] (up 0.8 percentage points). These trends are illustrated in Figure 5.4.

Figure 5.4
Industrial Energy Fuel Shares, 1990 and 1995 (percent)



* liquefied petroleum gases

The major shifts in fuel shares are concentrated in a few industries: mining, pulp and paper, and smelting and refining. In mining, the share of natural gas and oil products rose by 7.3 and 2.4 percentage points, respectively, at the expense of electricity, which decreased by 9.8 percentage points. This shift in fuel shares results from above average growth in the upstream and non-metal mining segments of the industry from 1990 to 1995, which rely heavily on natural gas and oil products.

In pulp and paper, the share of natural gas and wood waste and pulping liquor (included in "other fuels") increased by 0.4 and 6.1 percentage points, respectively, at the expense of oil products, which declined by 5.7 percentage points. Pulp and paper increased its share of wood waste and pulping liquor to produce steam and electricity as part of its climate change strategy that focused on reducing fossil fuel consumption and greenhouse gas emissions.

In smelting and refining, the share of electricit increased by 8 percentage points mostly at the expense of oil products (down 4.8 percentage points) but also at the expense of coal, coke, coke oven gas (down 2.1 percentage points) an natural gas (down 1.0 percentage point). The increased use of electricity in smelting and refining reflects the significant growth in aluminum manufacturing, which relies almost solely on electricity. Primary production of aluminum increased by 40 percent since the beginning of the 1990s. Aluminum accounts fo the bulk of the smelting and refining industry's energy use.

5.2 Evolution of Industrial Energy Use and its Major Determinants

As noted above, the growth in energy use from 1990 to 1995 was the major factor underlying the increase in emissions from the industrial sector. Had there not been the offsetting impac of carbon dioxide intensity, emissions would have increased at the same rate as energy use i.e., 9.1 percent.

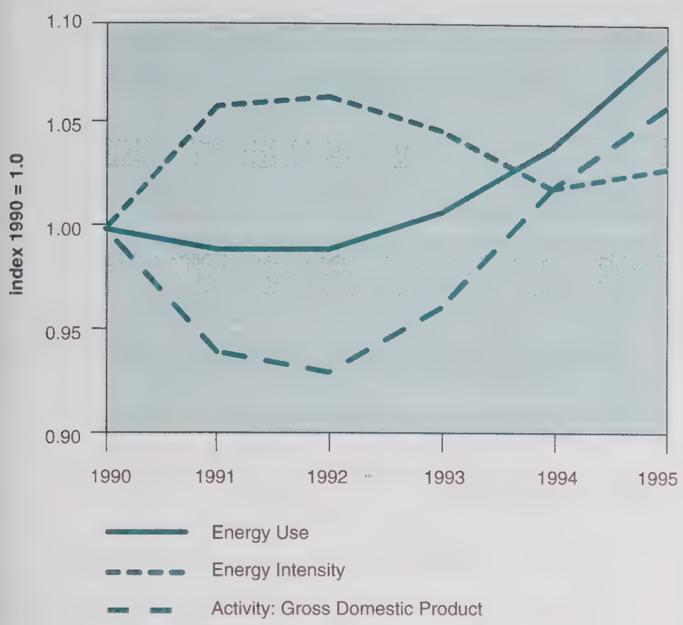
Figure 5.5 shows the trends in total industrial energy use, intensity and activity from 1990 to 1995. Over this period, energy use increased by 9.1 percent (average annual growth of 1.8 percent), from 2649 petajoules in 1990 to 2890 petajoules in 1995, while energy intensity[6] and activity increased by 3.0 and 5.9 percent (average annual growth rates of 0.6 percent and 1.2 percent), respectively. The evolution of energy use and its major dete minants was far from monotonic over these five years.

4 Almost 98 percent of "other fuels" are wood wastes and pulping liquor, all used in the pulp and paper sector. Wood wastes actually generate emissions the end use; however, using conventions developed by international organizations such as the Organization for Economic Cooperation and Development carbon dioxide emissions from these fuels are not counted if a nation's forests are managed in a sustainable manner.

5 As noted earlier in this report, electricity use does not generate emissions at the end-use level.

6 Industrial sector energy intensity is defined as industrial energy use divided by gross domestic product.

Figure 5.5
Industrial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



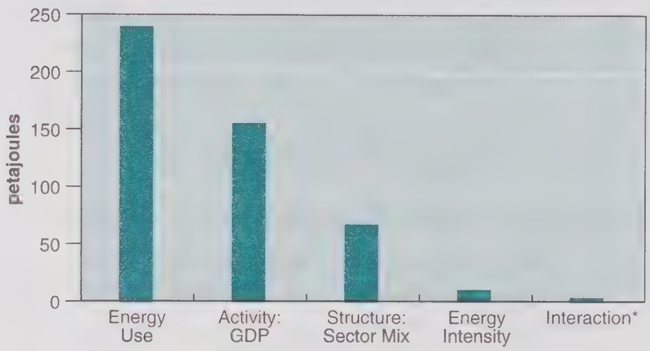
The 1990 to 1995 period can be divided into two very different sub-periods. The period 1990–1992 was largely influenced by the recession, while the period 1993–1995 reflects the experience of economic recovery. The trends in energy use vary significantly between these two periods.

Between 1990 and 1992, industrial activity declined by 7 percent. As is typical of periods of decelerating economic activity, energy use declined at a slower pace than activity because of the need to meet fixed energy requirements. As a result, energy intensity increased by 6.5 percent.

Between 1993 and 1995, the Canadian economy began to recover. Industrial energy use grew by 10 percent over this period. With activity growing at an even faster rate (14 percent over the period), energy intensity declined by 3.2 percent.

Factorization analysis[7] provides an alternative perspective on the change in total industrial energy use. This approach attributes the change in energy use over a given time period to activity and energy intensity. In this type of analysis, the effect of intensity is further decomposed into two separate parts: a structure effect (measured as the mix of economic activity among industries) and a "pure" energy intensity effect. The results of this analysis for the industrial sector are shown in Figure 5.6.

Figure 5.6
Factors Influencing Growth in Industrial Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Figure 5.6 shows that from 1990 to 1995, industrial sector energy use increased by a total of 241 petajoules. The factorization results for the period 1990 to 1995 can be summarized as follows:

- Industrial sector activity increased by 5.9 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 157 petajoules.
- The change in the mix of activity toward more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 68 petajoules.

7 In this report, only the factorization of aggregate industrial sector energy use using a 10-industry distribution of energy use and activity is discussed. In the database accompanying this report, an individual factorization of energy use is presented for each of the 10 industries. In this industry-specific analysis, structure refers to the fuel distribution of energy use.

Table 5.2
Summary of Trends in Energy Use, Activity and Energy Intensity in the Industrial Sector for the Six Largest Energy-Consuming Industries, 1990–1995 (percent change)

	Energy Use	Activity	Energy Intensity
Total Industrial	+9.1	+5.9	+3.0
Pulp and Paper	+17.4	+6.1	+10.7
Mining	+40.2	+23.1	+13.9
Petroleum Refining	-6.4	+2.1	-8.2
Iron and Steel	+9.9	+10.6	-0.6
Chemicals	-6.8	-4.0	-2.9
Smelting and Refining	+16.7	+27.9	-8.8

- There was a slight increase in energy intensity from 1990 to 1995. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have increased by 11 petajoules.

The energy intensity effect is much smaller than suggested by the 2.9 percent increase in aggregate intensity shown in Figure 5.5. This illustrates the analytical value-added of the factorization approach. In short, it shows that most of the change in the aggregate industrial sector energy intensity was due to a shift in activity mix (structure) rather than in industry-specific energy intensities.

The next three subsections describe the reasons underlying changes in activity, activity mix and intensity. In this discussion, the role of trends in these three factors in major industries is described. Table 5.2 situates aggregate trends in energy use, activity and intensity with respect to similar trends in the major industries.

5.2.1 The influence of growth in industrial activity – the activity effect

The factorization analysis results attribute as much as two-thirds, or 157 petajoules, of the change in energy use from 1990 to 1995 to growth in industrial activity. In aggregate, industrial activity rose by 5.9 percent, or $8.8 billion, over this period.

This section reviews activity developments in major industries. The review focuses on activity growth in branches of major industries. The objective of this review is to better understand the sources of growth in industrial activity. However, from this discussion, the reader will note that different branches of the industries reviewed grow at different rates, thereby suggesting shifts in activity mix within industries (e.g., shift to oil and gas mining from other types of mining in the mining industry). Two points are important to remember about these shifts:

- In this analysis, the effects of intra-industry shifts are not reflected in the structure effect presented in Figure 5.6. The structure effect identified in the factorization analysis only accounts for shifts among the 10 large industry groups for which a full set of energy use, activity and energy intensity information was available for the analysis.[8]
- The effect of shifts in the mix of activity within an industry are reflected in the energy intensity effect.

In short, only information on the direction of change in activity in the industrial sector as a whole is relevant to the activity effect. The implications of shifts within the industrial

8 The 10 industries used in the factorization analysis are the ones listed in Figure 5.1.

sector define the structure effect, which will be discussed in section 5.2.2.

Forestry, pulp and paper, sawmills

Since forestry and related manufacturing industries (pulp and paper, sawmills) are cyclically sensitive, their activity followed the general business cycle during the early to mid-1990s. These industries account for roughly 30 percent of all end-use energy in the industrial sector.

Activity for the industry declined in 1990–1991 but managed to climb back to 1990 levels by 1993–1994 and continued to improve in 1995. Domestic sales were relatively stable with the main source of increased demand originating from export markets. Exports of both pulp and newsprint surged from 1993 to 1995, and exports of other types of paper provided a strong underlying source of demand over the 1990–1995 period. Sawmill products also did quite well as lumber exports were stimulated by increased demand as a result of rebuilding after several natural disasters in the United States.

Mining

Mining gross domestic product is dominated by oil and natural gas mining, which accounted for over 60 percent of total mining activity in 1995. Over the 1990 to 1995 period, activity in the oil and gas branch expanded steadily, and by 1995, it was 32 percent larger than in 1990. Rapid growth in crude oil and natural gas exports was the main reason for the expansion; however, positive changes to tax and royalty schemes during this period also had a positive impact on growth. Mining services, closely tied to oil and gas mining, also did quite well over this period.

Activity growth in other branches of mining was weaker as a global economic slowdown hindered exports of a number of mining-related products. Iron mining recorded an overall gain in activity of 10 percent; however, activity was very weak from 1990 to 1993 before a recovery in iron ore exports stimulated increased production in 1994–1995.

In 1995, coal mining activity was 9 percent above the 1990 level. Coal exports struggled from 1990 to 1992 but rebounded and posted a 10 percent annual growth from 1993 to 1995. Consumption by intermediate users, such as electric utilities and iron and steel producers, was also weak in the early-1990s but recovered in subsequent years.

Non-metal mining accounts for only 3 percent of total mining activity and a small proportion of industrial energy use. Non-metal mining activity increased by 7 percent over this period, with most of the growth attributable to potash mining.

Petroleum refining

Growth in petroleum refining activity spurred industrial energy use upward. Despite the healthy activity increases recorded for producers of oil and natural gas, activity levels of petroleum refiners remained fairly stable over the 1990–1995 period, only managing a 2 percent gain.

Weakness in this industry was rooted in sluggish domestic consumer demand for such things as "other fuels" and lubricants and motors. Further, purchases by several major, intermediate buyers, such as air transport, and road and highway construction, declined as demand for their products fell. Fifteen percent of refined petroleum and coal products is exported, and slow U.S. industrial demand also limited activity to a great degree.

Iron and steel, smelting and refining

Iron and steel, and smelted and refined products are primary inputs for many manufactured goods and account for roughly 15 percent of total industrial energy demand. During the 1990–1995 period, fairly strong activity growth in these industries resulted in additional energy requirements.

Iron and steel activity recorded growth of 11 percent, while smelted and refined products grew by 28 percent. One of the primary reasons for increased activity was the exceptional growth of machinery and equipment investment in North America. In addition, production of motor vehicles surged ahead in 1992–1995, providing a strong source of demand for manufactured metal products.

Chemicals

Activity growth in the chemicals industry was fairly weak throughout the early to mid-1990s, with a 4 percent decrease recorded. Producers of non-industrial chemicals were adversely affected by their linkages to consumer demand and downsizing pressures in the health system. These industries include soap and cleaning compounds manufacturers, toilet preparations, pharmaceutical and medicines, and paint and varnish manufacturers. To make matters worse, among the primary users of industrial chemicals are cyclically sensitive, resource-based industries. These industries were hard hit during the recession of the early-1990s, which had a dampening influence on demand. However, by 1994–1995, recovering domestic sales and exports provided some impetus for increased activity.

Cement

Declines in construction activity also influenced the performance of other industries, including cement manufacturing. In 1995, gross domestic product in the cement industry was 15 percent below the 1990 level.

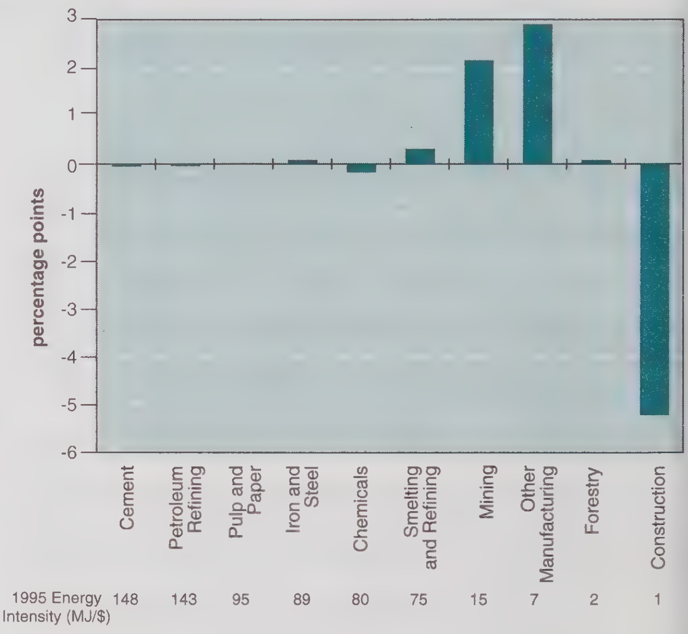
Exports of cement and related products to U.S. markets have done quite well over the past several years. But exports account for less than 20 percent of total sales, and the collapse of the domestic residential and non-residential building market has had an overwhelmingly negative impact on producers.

5.2.2 The influence of shifts in the distribution of industrial activity – the structure effect

From 1990 to 1995, there was a shift toward more energy-intensive industries. This shift accounts for 68 petajoules of the total 241-petajoule increase in energy use from 1990 to 1995.

Figure 5.7 presents the change in the shares of industrial activity (in percentage terms) accounted for by a selection of industries. At the bottom of the figure, the energy intensity of each industry in the year 1995 is presented. Increases in activity shares occur in the most energy-intensive industries, causing an upward influence on energy use.

Figure 5.7
Changes in Sectoral Shares of Industrial Activity, 1990–1995 (percentage points)



The figure shows that four of the seven most energy-intensive industries increased their share of energy use from 1990 to 1995 (pulp and paper, iron and steel, smelting and refining, and mining). Most of the shift occurred in the mining industry, which increased its share

by 2.1 percentage points during the period. Together these seven energy-intensive industries increased their share of industrial activity by 2.2 percentage points at the expense of the remaining three industries. The reasons underlying share shifts are directly related to the factors that have led to higher than average activity growth in some industries and lower than average growth in others. These factors are documented in detail in the preceding subsection.

5.2.3 The influence of variations in the intensity of industrial energy use – the intensity effect

The energy intensity effect measures how much energy use would have changed had industrial activity and its structure remained constant over the period and only energy intensity varied. The energy intensity effect for the industrial sector is positive (see Figure 5.6), indicating that, on average, industry-specific energy intensities increased from 1990 to 1995. In fact, if energy intensity had not changed from 1990 to 1995, energy use would have been 11 petajoules lower.

While the overall energy intensity effect for the industrial sector is positive, this does not imply that energy efficiency in the industrial sector has deteriorated. First, the increase in aggregate industrial sector energy intensity is a result of offsetting changes in specific industry groups, which are discussed in detail below. The aggregate result hides energy intensity declines in many large energy-consuming industries.

Second, the energy intensity effect reported in Figure 5.6 reflects much more than the trend in energy efficiency. It is important to remember that for the industrial sector the results presented in figure 5.6 only net out of aggregate energy intensity, in an explicit, quantitative way, the effect of industry activity mix. Data are not available to net out other effects such as changes in (i) the mix among the branches of an industry (e.g., in the mining industry, the increase in oil and gas vs. other types of mining), (ii) product mix, (iii) operating practices, (iv) fuel mix[9] and/or (v) process mix. Changes in any of these factors will be reflected in the energy intensity effect. For this reason, the following review of the energy intensity effect will cover as many of these factors, including energy efficiency developments, as possible.

On an industry-by-industry basis, energy intensity declined in the petroleum refining (8 percent), chemicals (3 percent), smelting and refining (9 percent), and iron and steel (0.6 percent) industries. Of the aggregate energy intensity effect of 11 petajoules, these four industries contributed a downward influence of 27, 7, 16 and 1 petajoules, respectively.

Conversely, energy intensity increased in the pulp and paper (11 percent), mining (14 percent) and cement (15 percent) industries. Of the aggregate energy intensity effect of 11 petajoules, these three industries contributed an upward influence of 79, 36 and 9 petajoules, respectively.

As was reported in other parts of this report, an economic measure of activity was used for the analysis in large part because of the requirements of the factorization analysis. However, other measures of activity can be used, particularly at the industry-specific level, in order to track variations of energy efficiency.

The Canadian Industry Energy End-Use Data and Analysis Centre (CIEEDAC), in collaboration with the Canadian Industry Program for Energy Conservation (CIPEC), has developed energy intensity indicators using physical

Since fuels have different conversion efficiencies, fuel substitution can result in changes in energy use at the secondary level. These fluctuations in secondary energy use are captured in the energy intensity effect.

measures of activity for a number of industries.[10] In the rest of this section, changes in energy intensity based on an economic measure will be discussed, but also, where available, results from the CIEEDAC report will be presented for comparative purposes.

The question of an appropriate denominator for energy intensity is the subject of an ongoing debate. At the aggregate level, it is impossible to find a common denominator other than dollars, and for this reason, economic measures are used for analysis. At the sectoral level, however, energy intensity based on physical measures of activity may be a better proxy for energy efficiency, especially in industries where products have remained relatively homogeneous over time (e.g., steel).

Intensity trends can differ significantly depending on whether the denominator is measured in economic (as is done in this report) or physical units. These differences are due in large part to the level of disaggregation at which the comparison is done. If data were available to compare results at a level of detail where the product/process is homogeneous, the results of the two measures would be comparable.

In the paper sector, for example, a typical physical measure of activity is tonnes of paper; an economic measure is the value of paper production. If, over the period under review, the mix of paper products shifts toward more energy-intensive, higher value and higher quality paper, both the economic and physical intensity measures will decrease. The economic measure, however, will not only reflect the effect on intensity of the change in the mix of production, but also the fact that the higher quality paper has a higher value, a phenomenon not at all related to energy efficiency or other physical processes that characterize paper making. This should be kept in mind when physical and economic measures of energy intensity are presented below.

Pulp and paper

Energy use in the pulp and paper industry increased faster than activity between 1990 and 1995. As a result, energy intensity increased by 11 percent over this period. Of the 11-petajoule energy intensity effect, an increase of 79 petajoules is attributed to developments in the pulp and paper industry. Some of the developments that have driven the change in this industry's energy intensity are fuel shifts and energy efficiency improvements.

Over the last decade, the share of oil products declined by 5 percentage points while the share of wood wastes and pulping liquor increased by 6 percentage points. The conversion efficiency of wood wastes and pulping liquor is less than that of fossil fuels. As a result, meeting the same end-use requirements using wood wastes and pulping liquor rather than oil products results in an increase in energy use. The impact of this change in fuel mix offset the effect of some of the energy efficiency improvements in pulp and paper industry processes.

One of the most significant energy efficiency improvements in the pulp and paper industry between 1990 and 1995 was a shift from chemical pulping and mechanical pulping to recycling. Producing pulp from recycled paper requires only about 17 to 23 percent of the energy required by chemical and mechanical pulping. Most recycled products in Canada are used in the production of new papers and boards. From 1990 to 1995, the share of paper and board production that came from recycled products increased from 11 to 22 percent.

Other energy efficiency improvements occurred between 1990 and 1995 through the upgrading of auxiliary equipment. For example, three high-efficiency soot blowers were installed on the recovery boiler of Avenor's Gold River Plant in British Columbia. This resulted in energy

10 Canadian Industry Energy End-Use Data and Analysis Centre, *Energy Intensity Indicators for Canadian Industry, 1990–1995*, Simon Fraser University, Burnaby, British Columbia.

savings of 40 percent for this operation. The Thunder Bay plant reduced the energy requirement of its thermomechanical pulping process by 20 percent since 1992 by improving its process control and by making other modifications to equipment such as a refiner plate redesign.

The pulp and paper energy intensity indicator presented in the CIEEDAC report shows a different trend than reported above. While this report uses gross domestic product, an economic measure of activity, the CIEEDAC report uses tonnes of pulp and paper, a physical measure. The latter[11] shows a decrease in intensity of 8 percent despite the switch to wood wastes and pulping liquor. Given the level of aggregation of the analysis presented in this report, it is not surprising that the two measures differ to such an extent. A much more detailed review would be required to fully understand the reasons underlying these two trends.

Mining

The intensity of energy use in the mining sector increased by 14 percent from 1990 to 1995. The factorization analysis attributes 36 petajoules of the 11-petajoule energy intensity effect to changes in energy intensity in this industry. Fuel switching and structural shifts within this industry toward more energy-intensive activity contributed to the upward trend in intensity.

From 1990 to 1995, the share of electricity in the mining industry decreased by 10 percent, and the share of natural gas and oil products increased by 11 percent. Since the conversion efficiency of electricity at the end-use level is much higher than that of natural gas and oil products, this shift resulted in increased secondary energy use.

As noted in section 5.2.1, the output of the mining industry increased by 23 percent over the period. The gross domestic product of this industry is dominated by the oil and gas branch (60 percent of activity in 1995), which increased by 32 percent from 1990 to 1995. The upstream oil- and gas-mining operations are generally more energy-intensive than the downstream metal- and non-metal mining processes. For example, the oil sands upgraders, which increased their production by nearly 58 percent between 1990 and 1995, use about five times more energy per tonne of product than metal and non-metal mining. This structural shift is partly responsible for the increase in energy intensity of the sector.

Also contributing to the increase in energy intensity from 1990 to 1995 is a shift in activity from metal mines to non-metal mines. Metal mines ore production decreased by 6 percent over the period, and non-metal mines production increased by 9 percent, mainly due to increased potash production. Metal-mining processes require about five times less energy than non-metal mining.

Petroleum refining

The petroleum refining industry recorded an energy intensity decrease of 8 percent from 1990 to 1995 in the face of low production capacity utilization rates. This decline alone contributed to limiting industrial energy use growth by 27 petajoules.

Some of the factors underlying the decline in energy intensity in the petroleum refining sector include fuel switching toward fuels with higher conversion efficiency (share of petroleum coke increased by 5 percentage points at the expense of natural gas, which declined by 6 percentage points), industry restructuring and energy efficiency improvements.

11 Note that the definition of the pulp and paper industry in the CIEEDAC report is slightly different from the one used in this report as it is exclusive of sawmills. However, sawmills only account for about 4 percent of the pulp and paper sector's energy demand.

From 1990 to 1995, the petroleum refining industry experienced major restructuring. Several refineries and distribution terminals were shut down, thereby improving the average efficiency of the remaining facilities.

Energy efficiency improvements in this industry focused on better operation and upgrade of equipment, especially the auxiliary systems. For example, in Shell refineries, advanced control and optimization technologies were used to improve the efficiency of heaters and boilers and to optimize refinery steam systems, more variable speed drives were used, pumps were upgraded to more efficient equipment and lighting levels and use were reduced.

The reduction in intensity for this sector is slightly less if a physical indicator of production is used. For the petroleum refining industry (excluding lubricating oil and grease, which only account for 2 percent of the sector's energy use), energy intensity, using cubic metres of various fuels as a denominator, decreased by less than 2 percent.

Iron and steel

Energy intensity in the iron and steel industry decreased slightly (1 percent) from 1990 to 1995. The factorization analysis attributes a downward influence on the aggregate energy intensity effect to the order of 1.4 petajoules for this industry. Given that energy efficiency improvements are difficult to achieve with low production capacity utilization rates, as was the case for this industry in the beginning of the period, the apparently modest decline in energy intensity is significant.

An important technological change in this industry is the continuous shift to the electric-arc furnace (EAF) technology, which uses 100 percent scrap metal and only about 13 percent of the energy of an integrated mill (about 2 gigajoules of energy per tonne of molten steel, rather than 15 gigajoules per tonne). In 1990, EAFs using metal scrap were used to produce approximately 37 percent of the steel production, compared with about 39 percent today. The remaining steel is produced in integrated mills with basic oxygen furnaces that use a mix of pig iron and metal scrap.

The shift from integrated mills to EAFs caused some fuel switching, a trend that contributed to limiting energy use growth. From 1990 to 1995, there was a 4 percentage point reduction in the share of coke and coke oven gas and a 6 percentage point increase in the share of natural gas in this industry.

Process change was not the only reason for fuel switching. An example of additional fuel switching to natural gas occurred at the Stelco, Lake Erie Steel Company where natural gas injection was added to the blast furnace to reduce coke consumption. Since the conversion efficiency of coke and coke oven gas is less than that of natural gas, less input energy is required to meet the same energy requirements with natural gas. This results in a decline in secondary energy use and intensity. Energy savings were also realized because less coke needs to be produced in the plant's coke ovens.

The decrease in energy intensity in the iron and steel industry was also influenced by improvements in the semi-finished and finished stages of production. Investments have been aimed at replacing ingot casting with continuous casting, which bypasses the semi-finished stage. Use of continuous casting increased from 77 percent in 1990 to nearly 97 percent in 1995. Depending on the product being manufactured, continuous casting can reduce the energy requirements of the casting process by 50 to 90 percent. Other significant improvements focused on reducing the reheating requirements for hot rolling into the final shape of the product and improving the efficiency of auxiliary equipment, mainly motors, pumps and lighting.

The energy intensity decline is similar using physical units of activity. In the CIEEDAC report, the "other primary steel" industries, which account for about 98 percent of the iron and steel industry, show an energy intensity decline (based on tonnes of steel) of 3 percent over the period.

Smelting and refining

The energy intensity of this industry declined by 9 percent from 1990 to 1995. The factorization analysis attributes a downward influence on the aggregate energy intensity effect in the order of 16 petajoules for this industry. Despite significant growth in production levels, the industry has managed to limit its energy consumption through a combination of fuel switching and energy efficiency improvements.

From 1990 to 1995, there was a shift from coke, coal and oil products (a decline of 7 percentage points) to electricity (percentage point increase of 8). Since the conversion efficiency of coke, coal and oil products is much less than that of electricity, this contributed to the decline in energy intensity.

As for process changes, aluminum production in Canada has become much more energy-efficient since 1990 as some old Soderberg-type smelters were replaced with more efficient smelters. For example, Alcan replaced 10 Horizontal-stud Soderberg smelters with a more efficient plant, Laterrière Works, in 1989. The old Horizontal-stud Soderberg smelters used about 18 to 19 megawatt-hours of electricity per tonne of aluminum, while the newer smelters used at Laterrière consume about 15 megawatt-hours per tonne. Two other plants, Aluminerie Lauralco Inc. and Aluminerie Alouette Inc., started operating in 1992 using the more efficient prebake Pechiney technology. This type of smelter uses as little as 14 megawatt-hours of electricity per tonne of aluminum.

The smelting and refining industry relies heavily on electricity (79 percent of the sector's energy use in 1995); therefore, improvements have also focused on improving the energy efficiency of electricity generation turbines.

Chemicals

A slight decline in energy intensity in this sector contributed to a reduction in industrial energy use growth by 7 petajoules over the period. Major factors affecting the change in energy intensity include fuel shifting and changes in the product mix.

Over the past five years, the chemical industry reduced its share of heavy fuel oil and steam by 7 percentage points and increased its share of natural gas and electricity (which both have higher conversion efficiencies than the former two) by 7 percentage points.

Another factor contributing to the overall decrease in energy intensity was the shift in product mix from chlorine and caustic soda to sulphuric acid. Chlorine and caustic soda are coproduced as part of a single process (chlor-alkali production), which uses about 30 gigajoules of energy per tonne of product. Sulphuric acid, on the other hand, only uses about 0.03 gigajoules of energy per tonne of product.

Cement

Energy intensity in the cement industry increased by 15 percent between 1990 and 1995. The factorization analysis attributes an upward influence on the aggregate energy intensity effect to the order of 9 petajoules for this industry. As for many of the sectors discussed in this section, fuel shifting and energy efficiency developments influenced the change in intensity.

From 1990 to 1995, the share of natural gas used by the cement industry decreased by 3 percent benefitting the coal, coke and oil

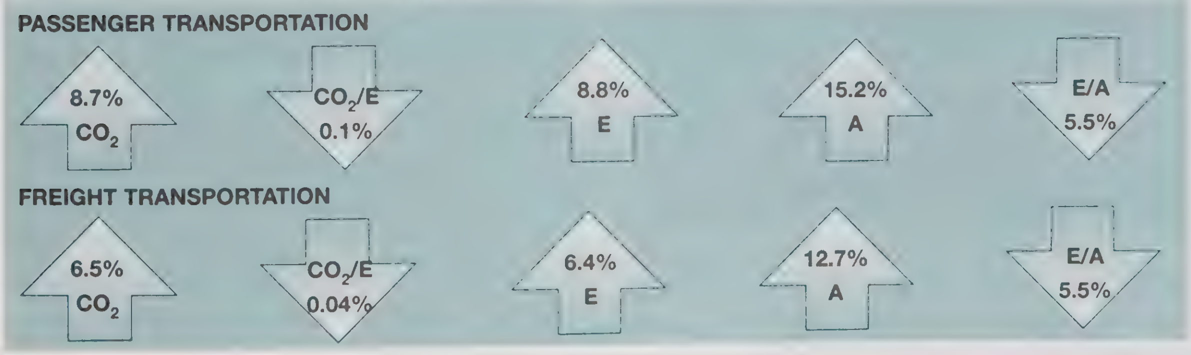
products' share, which increased by 2 percent. This had a positive impact on the sector's energy use.

Two developments in the cement industry, the move to less energy-intensive dry processes and more efficient auxiliary technologies, point to improved energy efficiency and lower energy intensity. For example, since 1990, two old technology-based plants (in Winnipeg, Manitoba, and Regina, Saskatchewan) were closed, long dry kilns in Picton, Ontario, were retired and wet kilns in Bowmanville, Ontario, were replaced by efficient dry technologies, which use preheaters and precalciners. Dry kilns with preheaters or precalciners use between 3.3 and 3.6 gigajoules per tonne of clinker, while long dry kilns and wet kilns use 4.5 to 5.3 and 6.0 to 6.3 gigajoules per tonne of clinker, respectively.

Transportation Sector

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) increased by 7.9 percent from 1990 to 1995, almost entirely due to an increase of comparable magnitude in energy use.
- Motor gasoline accounts for 59 percent and diesel fuel for 26 percent of total transportation energy use. Between 1990 and 1995, there was a 2 percentage point shift from motor gasoline to diesel, which contributed to a slight decline in the carbon intensity of transport fuel.
- Transportation energy use (E) is dominated by the passenger segment, which, in turn, is dominated by cars and vans. From 1990 to 1995, passenger transportation energy use increased by 105 petajoules, or 9 percent, while freight transportation energy use increased 42 petajoules, or almost 7 percent.
- Several factors caused transportation energy use to change over the 1990 to 1995 period:
  - Energy and emissions increased because activity (A) increased—more people, more vehicles, more kilometres. Activity changes were the most significant factor causing energy use to increase from 1990 to 1995. Had activity not changed, passenger and freight transportation energy use would have been 176 petajoules and 82 petajoules lower, respectively, in 1995 than they actually were.
  - The impact of structural change, or mode shifts, in the passenger segment was small, increasing energy use 2 petajoules. The impact of structural change in the freight segment—a modal shift toward trucks—was more pronounced. If this structural change had not occurred, energy use would have been lower by 104 petajoules in 1995.
  - Had passenger subsector energy intensity (E/A) not declined, energy use would have risen an additional 56 petajoules from 1990 to 1995. Within the freight subsector, had energy intensity not declined, energy use would have risen an additional 116 petajoules.



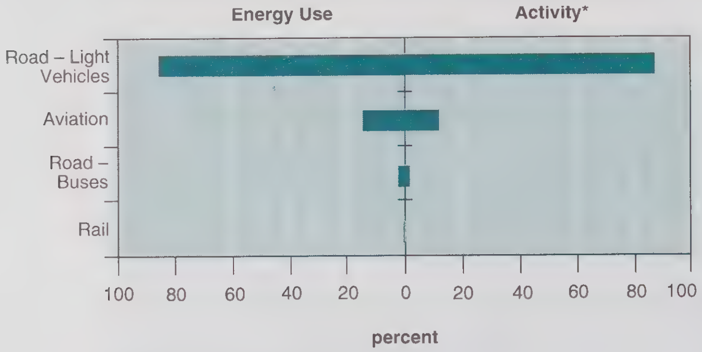
The transportation sector includes passenger and freight transportation. The passenger subsector is the largest subsector of transportation, accounting for 65 percent of transportation energy use. Each subsector uses four modes: road, rail, air and marine.

Road transport is the most popular mode in both subsectors, as shown in Figure 6.1 and 6.2. It accounts for almost all of the energy in both segments and almost all of the kilometres in the passenger subsector.[1] Road transporta-

There is an availability and quality dimension to passenger transport activity data. On the former, passenger transport activity (passenger-kilometres) does not include the non-commercial airline segment, for which there is no time series data. On the quality issue, passenger-kilometre numbers exist for rail and air, while numbers for road light vehicles and buses are calculated on the basis of other data. Where estimates are used, an effort is made to substantiate the estimated trends with survey data.

tion is, in turn, dominated by light vehicles in terms of both energy use and passenger-kilometres, accounting for more than 80 percent of both in the passenger subsector and more than half of the energy in total transportation.[2]

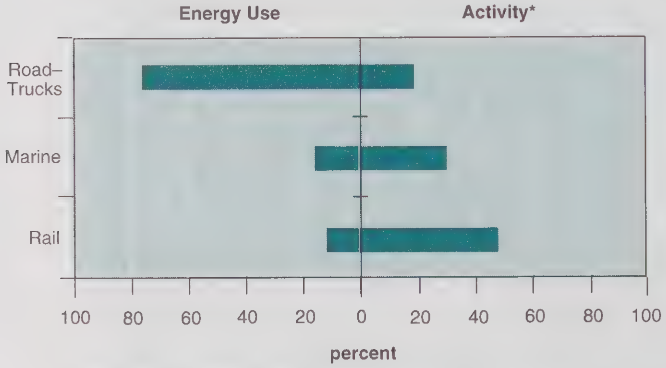
Figure 6.1
Distribution of Passenger Transportation Energy Use and Activity by Mode, 1995 (percent)



* Measured in passenger-kilometres

Within the freight subsector, trucks account for 74 percent of the energy use, while marine accounts for 15 percent and rail for only 12 percent. Because of the partial truck activity data, rail accounts for 48 percent of total freight tonne-kilometres.[3]

Figure 6.2
Distribution of Freight Transportation Energy Use and Activity by Mode, 1995 (percent)



* Measured in tonne-kilometres

Energy use per passenger-kilometre, or aggregate intensity, differs by mode. In the passenge segment, the largest difference is between rail and all other modes. Rail is the least energy-intensive mode, while all other modes are roughly 25 percent more fuel-intensive per passenger-kilometre. Air is slightly more energy intensive than road, but over long distances, it can be the most time efficient mode. On average, light vehicles are slightly more energy intensive than buses. In the freight segment, rail energy-intensity is low, as is route flexibility. Several factors are considered in the choice of mode, one of which is energy use. While energy and its price are important, it is necessary to recognize the role of other key variables such as time, route, flexibility and convenience, in fuel and mode choices.

In this chapter, the growth in carbon dioxide emissions from 1990 to 1995 and the principal reasons for this growth, the most important of which is increased energy use, are examined. The bulk of this report focuses on the factors that contribute to increased energy use. First, passenger transportation is addressed. In this subsector, the focus is on road and, within it, light vehicles. This is followed by a separate section on freight.

Carbon dioxide emissions from the transportation sector[4] increased by almost 8 percent (or an average annual rate of 1.5 percent) from 126.8 megatonnes in 1990 to 136.7 megatonne in 1995. Figure 6.3 presents a breakdown of emissions by mode in 1990 and 1995. The most striking feature of this graph is that all of the growth in emissions comes from road transport—passenger vehicles and buses and truck freight.

2 Light-duty vehicles include small cars (up to 1180 kg, or 2600 lb), large cars (more than 1180 kg) and trucks (up to 4545 kg, or 10 000 lb, of gross vehicle weight). North America alone there are several different categorization methods used to separate vehicles by size, including the interior car space classification commonly us in the United States. This makes comparisons difficult. Finally, it is worth noting that our "large car category" is typically broader than that used by others. For freig small trucks are less than 4545 kg, medium-sized trucks are 4545 to 15 000 kg (33 069 lb) and large trucks are greater than 15 000 kg.

3 Freight activity data, defined as tonne-kilometres, is also partial as it covers all rail and marine, but only a portion of trucks. Road freight activity is limited to large commercial trucking since it includes only intercity activity by Canadian-domiciled, for-hire trucking companies with annual revenue of at least $1 million. In the 1996 report, road freight activity covered domestic freight only. This year, activity has been expanded to include the Canadian portion of international freight, both export destined and import freight. For reference, large trucks, more than 15 000 kg, account for more than 60 percent of freight energy use and, therefore, at least this share of tonne-kilometres. In addition, marine freight tonne-kilometres, which were absent from last year's report, are now reflected in this report.

4 The definition of transportation energy demand, and related carbon dioxide emissions, used in this report differs from the one used by Environment Canada in *Trend in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, emissions from the transport sector in this report are lower than Environment Canada's by 13.2 megatonnes in 1990 and by 13.7 megatonnes in 1995. See Appendix D for documentation of differences.

Figure 6.3
Transportation Carbon Dioxide Emissions by Mode, 1990 and 1995 (percent)

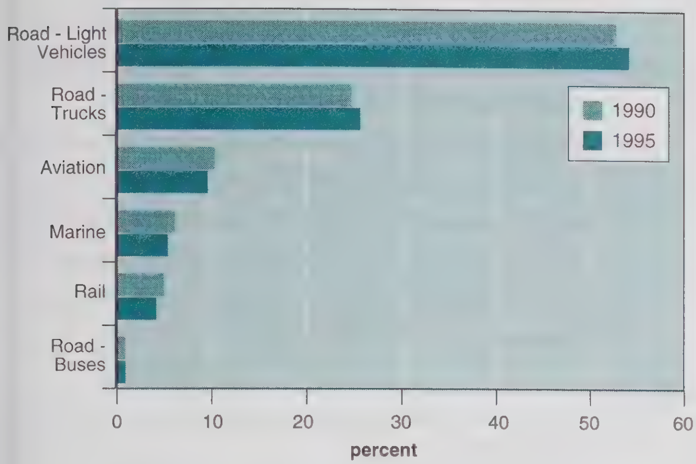


Figure 6.4 shows the changes in carbon dioxide emissions, energy use and carbon dioxide intensity over the period 1990 to 1995. Since this sector is so highly dominated by a few fuel types and the shares of these fuel types are relatively stable over the 1990 to 1995 period, the trend in emissions mirrors the trend in energy use over the period.

Figure 6.4
Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

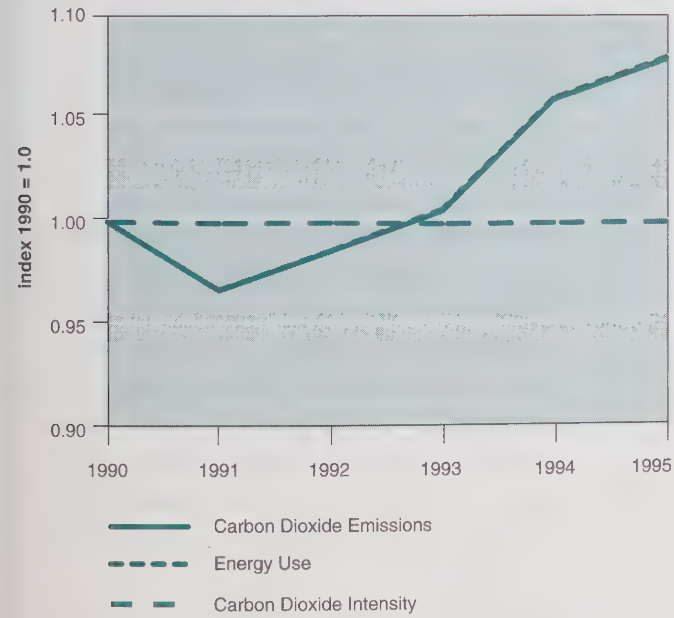
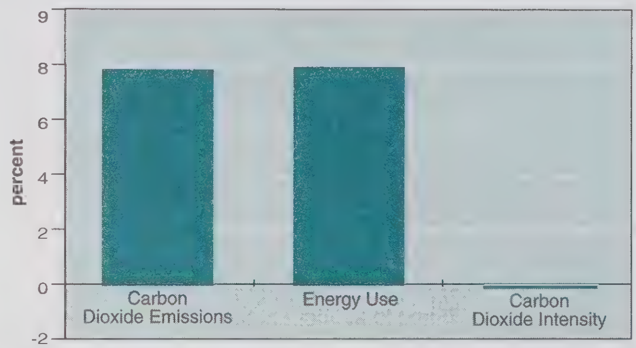


Figure 6.5 confirms the dominant influence of changes in energy use on changes in carbon dioxide emissions. The increase in carbon dioxide emissions from 1990 to 1995 is almost entirely driven by growth in energy use. Energy use increased by 8 percent (or an average annual growth rate of 1.5 percent), from 1839 petajoules in 1990 to 1986 petajoules in 1995. At the same time, the average carbon dioxide intensity of transportation fuels declined only slightly. Therefore, the remainder of this chapter addresses the evolution of tranportation energy use and its major determinants.

Figure 6.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1995 (percent)



6.1 Evolution of Passenger Transportation Energy Use and its Major Determinants

Passenger transport energy use increased 105 petajoules, or 9 percent (an average annual growth rate of 1.7 percent), from 1195 petajoules in 1990 to 1300 petajoules in 1995. Most of this increase was in the road segment, which increased 107 petajoules, or 11 percent. Total passenger activity increased by about 82 million passenger-kilometres, or 15 percent, between 1990 and 1995, of which the road segment accounted for 78 million. Road segment activity increased 17 percent between 1990 and 1995. Within the road market, small

vehicles continue to account for more than half of light vehicle road passenger-kilometres. Light trucks, which include minivans, account for 17 percent of road passenger-kilometres but are the fastest growing vehicle type.

NEW ROAD TRANSPORT SURVEY!

Over the past year, the *National Private Vehicle Use Survey* (NaPVUS) was completed by Statistics Canada for NRCan. Through this survey, NRCan collected data on private vehicle use and fuel consumption and identified some of the factors that may affect this consumption. The release in October 1996 of the first set of data from NaPVUS, which covers the fourth quarter of 1994, represents the culmination of efforts to re-establish a process for the collection of data that will improve the tracking of market trends in this important energy-consuming sector.

This survey was undertaken quarterly from October 1994 through September 1996. Plans are to resume data collection in two to three years. This new survey bridges the information gap that has existed since the termination of Statistics Canada's *Fuel Consumption Survey* in 1988. Effort now will be focused on analysing the 1994 data now available and those for years 1995 and 1996 that will become available in the coming months.

Due to the recent availability of NaPVUS data, it has not been possible to include it fully in this analysis. Following review and assessment, NaPVUS data will be incorporated into the database and used in future analyses.

Some of the key results from NaPVUS are:

On-road Fuel Economy

- the average vehicle uses 11.8 L/100 km;
- passenger cars (including minivans) average 10.8 L/100 km;
- the average fuel use for 1993–95 passenger cars is 10 litres; pre-1993 models average 11.1 litres;
- light trucks (including full-size vans) average 15.6 L/100 km;
- 1993–95 model light trucks average 14.2 litres; pre-1993 average is 15.9 litres; and
- on-road fuel consumption has improved 14 percent between '87 and '94 for all vehicles, 16 percent for passenger cars and 11 percent for light trucks.

Fuel Economy Test versus On-road Use

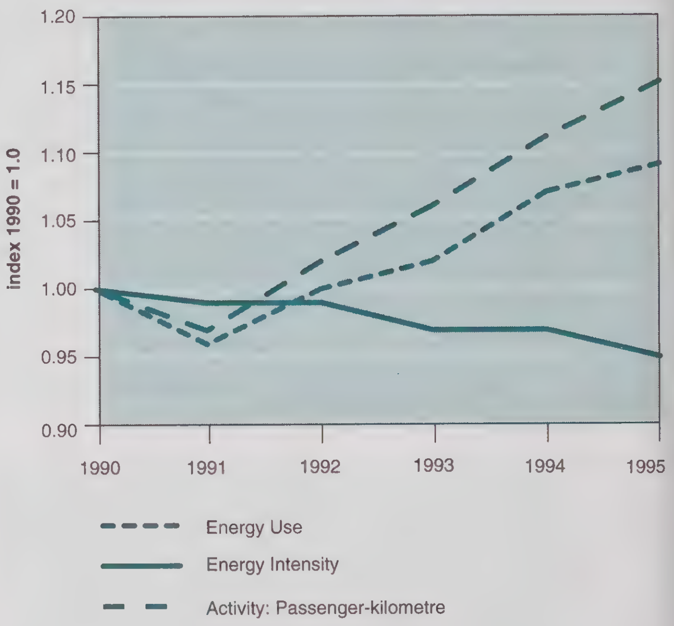
- the difference between Fuel Consumption Ratings and actual use for all vehicles is 28 percent, similar to 1987; and
- the difference for passenger cars and light trucks are respectively 24 percent and 35 percent; both similar to 1987.

Activity

- average distance driven for all vehicles was 4330 km during the October-December quarter of 1994; 4390 km for passenger cars and 4320 km for light trucks; and
- average distance travelled for all vehicles has increased 17 percent since 1987; 19 percent for passenger cars and 11 percent for light trucks.

Figure 6.6 shows that the growth in passenger transportation activity outpaced the change in energy use from 1990 to 1995. As a result, aggregate passenger transport energy use intensity, measured as fuel per passenger-kilometre, has fallen over the period 1990–1995.[5] Aggregate energy intensities declined for each mode except for buses. This aggregate intensity encompasses the effects of a wide range of factors, including fuel switching, technological improvements, modal shifts and behavioural change.

Figure 6.6
Passenger Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

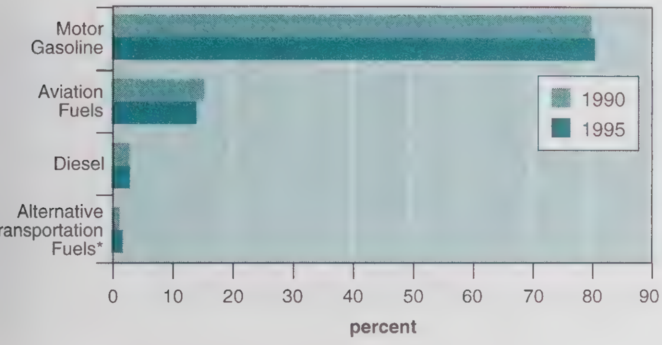


Later in this chapter, the influence of key variables on energy use change in each of the key subsectors is factored out. One of these factors is energy intensity. This measure of intensity will not be the same as shown in the factorization analysis. The factored intensity estimate is a cleaner estimate in that it excludes the impact of activity growth and modal shifts.

5 In this report, aggregate energy intensity is defined simply as the ratio of energy used over distance. In the case of passenger transport, the ratio is energy per passenger-kilometre. For freight, it is energy per tonne-kilometre.

Figure 6.7 shows that passenger transportation fuel shares did change slightly from 1990 through 1995. The share of motor gasoline increased moderately from 80 to 81 percent, while alternative transportation fuels, including propane and natural gas, increased from 1.4 percent to nearly 2.0 percent. The fuel share accounted for by aviation fuels declined. The increase in alternative transportation fuels was due to an increase in the use of propane and natural gas in light vehicles. The growth rate in natural gas use was high due to the low base.

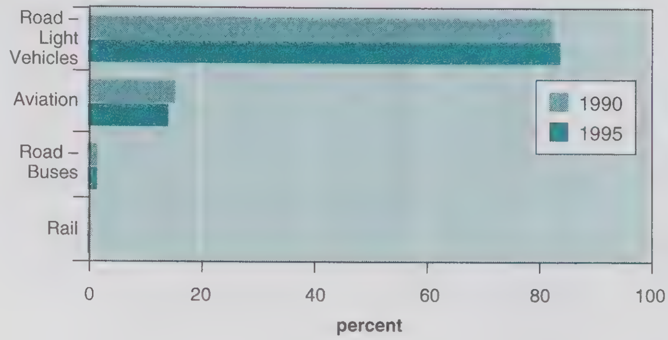
gure 6.7
assenger Transportation Fuel Shares, 1990 and 1995 (percent)



* Includes propane, natural gas and electricity

The distribution of passenger transportation energy use by mode changed marginally from 1990 through 1995. Figure 6.8 shows there was a modest shift toward light vehicles at the expense of all other modes. Light vehicles increased their share from 82.4 to 84.0 percent, while aviation's share declined from 15.5 to 14.2 percent and rail's share declined from 0.4 to 0.2 percent.

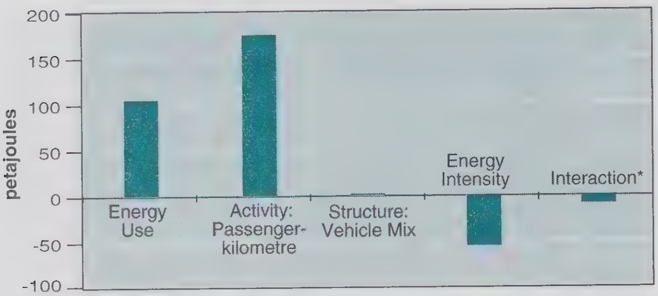
Figure 6.8
Passenger Transportation Energy Mode Shares, 1990 and 1995 (percent)



In Figure 6.9, the impact of factors that have contributed to the 105-petajoule increase in passenger transportation energy use between 1990 and 1995 are isolated.[6] The method factors out the impact of activity (total passenger-kilometres), structural shifts (between mode types) and energy intensity on the change in passenger transportation energy use. Figure 6.9 illustrates that, for this period, two factors are important: activity and intensity. Between 1990 and 1995, passenger-kilometres increased 15 percent to 626 million passenger-kilometres. About 85 percent of this activity increase is attributable to the light vehicle segment. Had only activity changed, passenger transportation energy use would have increased by 176 petajoules, rather than the observed increase of 105 petajoules. Therefore, some other factor dampened the influence of this activity.

The change in energy use that is shown in Figure 6.9 is the actual change for this sector, which is 105 petajoules. However, the sum of the factor impacts (ie., activity, structure, intensity and interaction effects) adds up to 112 petajoules because the factorization analysis excludes the non-commercial airline segment. An additional, but less significant, reason for the difference is the use of a motor gasoline equivalency value for the alternative transportation fuels.

Figure 6.9
Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Energy intensity is the most important factor offsetting the influence of activity on changes in energy use. Had energy intensity not declined, passenger transportation energy use in 1995 would have been almost 56 petajoules higher than it was. Fifty-one petajoules of energy intensity gain came from the light vehicle market. Within this segment, more than half of the intensity gains came from large cars and another quarter from small cars.

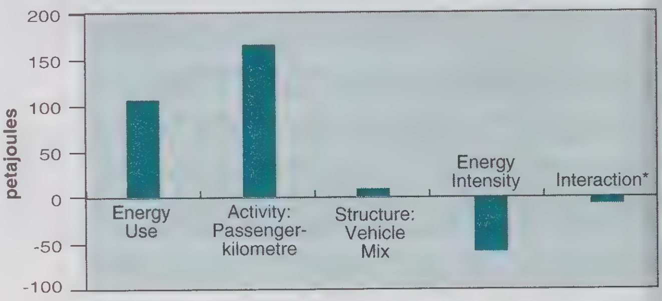
As shown in Figure 6.9, structural shifts were not significant in explaining the change in total passenger energy use. A small shift in passenger transportation modes, mostly from rail to road, modestly increased passenger transport energy use from 1990 to 1995. Since road vehicles are more energy-intensive than rail, this mode shift alone would have increased energy demand 2 petajoules had all other factors remained at their 1990 levels.

These factorial indicators show that increased activity in the form of more passenger kilometres and declines in energy intensity account for most of the change in passenger transport energy use between 1990 and 1995. These factors are discussed in more detail in the following four subsections, with emphasis on activity, which is the largest factor affecting changes in energy use. The discussion of the road segment provides a separate decomposition of factors for light vehicles (cars and light trucks) and buses. More attention is devoted to light vehicles since these account for most passenger transportation energy use—84 percent in 1995. The subsections on air and rail describe their respective contributions to the change in total passenger energy use.

6.1.1 Light vehicles

Figure 6.10 shows the factorial indicators contributing to the 106-petajoule increase in light-vehicle road transportation energy use from 1990 to 1995.[7]

Figure 6.10
Factors Influencing Growth in Light-Vehicle Passenger Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Again, the most important factors are activity and energy intensity. From 1990 to 1995, light-vehicle activity, defined as passenger-kilometres driven, increased an estimated 17 percent. If only activity had changed over this period and all other factors had remained at their 1990 levels, energy use would have increased by 166 petajoules instead of the actual increase of 106 petajoules.

A number of causal indicators help to explain the observed increase in passenger-kilometres. First and foremost, there are more people and more cars. There were half a million more people and six hundred thousand more cars in 1995 than in 1990. In addition to the population increase, a greater portion of the population is of driving age than ever before.

7 The change in total energy use presented in Figure 6.10 differs slightly from the actual change in light-vehicle passenger transportation energy use because the factorization of energy use for this subsector uses a motor gasoline energy equivalency value for alternative transportation fuels.

The ratio of licensed drivers to population has risen from 64 percent in 1990 to 66 percent in 1995. Moreover, these people seem to be driving their cars more each year. The average distance driven per passenger vehicle appears to have risen to 18 500 kilometres in 1995 from 17 400 kilometres in 1990.[8] Several indicators are consistent with this apparent trend to drive more per year. Changes in relative prices, which influence mode choice, support a shift to vehicle travel. The marginal cost of driving a private vehicle has fallen relative to the cost of urban, intercity and rural bus transport. Some of the cost indicators that are consistent with driving more include:

- Public
  The average cost of public transit has risen 34 percent since 1990.[9]
- Private
  Total variable costs are up about 14 percent since 1990, and new and used car prices are up about 20 percent.[10] At the same time, the average cost for parking increased 31 percent. However, the real price of gasoline declined 12 percent since 1990, and the ratio of variable to total driving costs declined 11 percent since 1990.

In addition to price changes favouring increased private vehicle travel, the rationalization of many bus routes has likely led to reduced frequency, lower convenience and increased time cost associated with bus transport.

Real disposable income per capita declined between 1990 and 1995, which typically has a dampening influence on passenger-kilometre activity. However, this decline would also induce consumers to substitute cheaper road vacations for international air travel, the latter of which declined 18 percent between 1990 and 1995. Moreover, favourable exchange rates contributed to a 22 percent increase in foreign travel to Canada, which supported increases in passenger-kilometre activity for all modes. Combined, these causal indicators help to explain why individuals drive their vehicles more kilometres per year.

One factor mitigating the increase in light-vehicle transport energy use was the decline in energy intensity. Had energy intensity not changed from its 1990 level, energy use would have been 60 petajoules higher than it was. There are two principal reasons for this intensity change. First, new car fuel economy, defined as litres per 100 kilometres, has typically declined each year. Figure 6.11 shows average new and average vehicle stock fuel economy since 1978. The most rapid fuel economy improvements occurred between the mid-1970s and through the early 1980s, in large part because the newer vehicles weighed less and had less power compared to their 1970s counterparts.[11,12] In the 1990s, the trend has been to increase power, which has slowed new car fuel economy improvements.[13]

The actual increase in passenger-kilometres is not known with certainty since this number is estimated from other data. However, NAPVUS survey results support the trend to increased travel.

The causal factors that encourage individuals to substitute private vehicle travel for public transportation are complex since they include both explicit and implicit costs, such as the value of time in commuting.

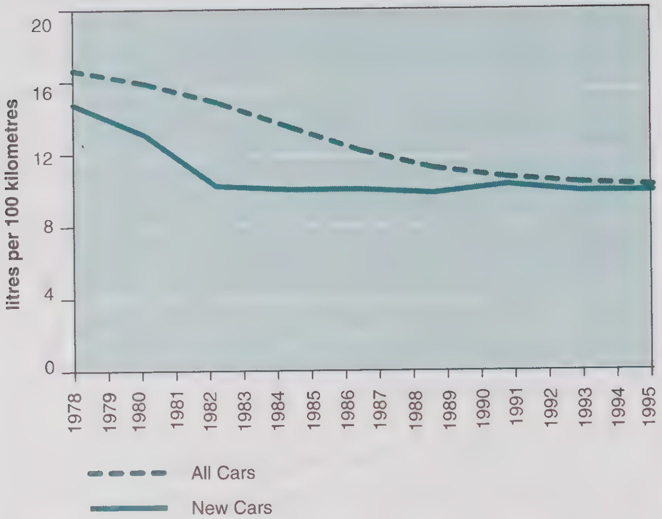
0 Variable costs include fuel, tires and maintenance, and fixed costs include depreciation, insurance and licensing. Cost data is from the Canadian Automobile Association's (CAA) annual publication *Driving Costs*.

1 Average horsepower ratings for new cars declined from the mid-1970s through to the 1980–1981 period when they levelled out at 99. Since then, horsepower ratings have stayed the same or increased marginally each year. Since 1993, horsepower ratings have increased 12 percent. At the same time, engine size, as measured by displacement, declined from the mid-1970s through to 1988. Engine displacement has been inching upward since then. In spite of the latter, engines have typically become more efficient in that the horsepower to engine size ratio has increased almost every year since 1976.

2 Technological improvements that have improved fuel economy also include improvements to the drivetrain (increased number of gears, electronic overdrive, lubricants that reduce drivetrain friction) and engine (electronic controls and better valve controls) as well as improved aerodynamics (reduced wind resistance, tires with less road resistance).

3 While fuel economy, measured as L/100 km, has not declined much in the 1990s, fuel efficiency may have declined. The indicator L/100 km is a measure of fuel intensity rather than fuel efficiency. Some additional transport indicators are required to get closer to measuring fuel efficiency. Some of these are suggested in the sidebar titled "Transport Indicators: The Need for Additional Indicators to Understand Trends."

Figure 6.11
Trends in Car Fuel Economy, 1978–1995 (litres per 100 kilometres)



The second factor affecting intensity is that new sales continue to displace older vehicles that have considerably lower fuel economy. The new car fleet is typically a combination of new additions as well as replacements for vehicles that are scrapped. Since replacement sales displace vehicles from each vintage, the fuel economy gain for the fleet depends on the vintage and fuel economy of those vehicles being replaced compared to new vehicles. In mid-1994, about 7 percent of the vehicle stock was 1970s vintage compared to nearly 19 percent in 1990.

The reduced share of 1970s vintage vehicles has been replaced by vehicles whose fuel economy is considerably better, as shown in Table 6.1.

Over time, fuel economy improvement has been diminishing and, therefore, the difference between the average stock and new stock is diminishing over time. If this continues in future years, the gain from stock turnover will diminish.

TRANSPORT INDICATORS: THE NEED FOR ADDITIONAL INDICATORS TO UNDERSTAND TRENDS

The traditional measure of transport fuel economy is L/100 km. This is a good aggregate indicator of intensity. However, a measure of efficiency typically assumes similar service characteristics over time. In the case of transport, safety, comfort and vehicle performance characteristics have changed considerably. As a result, alternative indicators may need to be developed that account for the changing nature of transportation today compared to yesterday. Some of these alternative indicators of fuel economy show that fuel economy has not been stagnant since the mid-1980s. For example, both L/100 km/kg and L/100 km/hp show different declines than L/100 km over the same period. In future reports, efforts will be made to include additional transportation indicators to better understand changes in fuel economy and fuel efficiency over time.

The impact of structural shifts (between small cars, large cars and light trucks) was relatively small in aggregate and different than it has been in the past. The trend to smaller vehicles

Table 6.1
Age Distribution and Characterization of the Vehicle Stock, 1990 and 1995 (1)

Year/Vintage	1970s Vintage (and older)	1980s Vintage	1990s Vintage
Stock Share in 1990 (percent)	19.0	76.0	6.0
Stock Share in 1994 (percent)	7.0	60.0	33.0
Fuel Economy (2) (L/100 km)	16.4	10.6	10.1
Weight (3) (tonne)	2	1.5	1.6
Power (hp)	135	100	140

(1) Dates on vehicle stock share are based upon vehicle registration data, which have been provided by Desrosiers Automotive Research Inc. For both 1990 and 1994, the estimate is from July. Data are not yet available for 1995.

(2) Fuel economy is a stock-weighted estimate for stock in each period. Actual on the road fuel use is typically higher. New vehicle fuel economy ratings for each model year are sales-weighted averages based on Transport Canada's fuel consumption rating calculated from vehicle fuel economy and emissions system data.

(3) The characterization indicated here is intended to highlight the most important features of vehicle design that impact on fuel economy.

that began in the 1970s has been reversed in the 1990s by a visible consumer preference for light trucks and vans.[14] The aggregate impact of a modal shift to light trucks relative to small and large cars, with all other factors remaining the same, was to increase energy demand by 9 petajoules.

6.1.2 Bus travel

Bus transport, which consists of urban and intercity, accounts for less than 2 percent of passenger transport energy use and less than 2 percent of passenger-kilometres. Urban buses are the most important, accounting for 18 of 21 petajoules of energy use in 1995.

Total bus energy use increased 1.3 petajoules between 1990 and 1995. Interurban energy use fell slightly while urban energy use increased. Bus activity levels (passenger-kilometres) fell from an estimated 12.6 billion passenger-kilometres to 10.6 billion. Intercity bus activity declined from 4.5 to 3 billion passenger-kilometres while urban activity declined from 8.1 to 7.5 billion passenger-kilometres. Therefore, there was a relative shift in activity from intercity to urban. If only activity and its mix had changed, bus travel energy use would have declined 3.2 petajoules.[15] Had only intensity changed, energy use would have increased 4 petajoules. This deteriorating intensity reflects, among other things, fewer riders and lower capacity utilization levels.

6.1.3 Aviation[16]

Aviation accounts for 14 percent of passenger energy use and 12 percent of passenger-kilometres. Between 1990 and 1995, energy use increased 4 percent to 152 petajoules while passenger-kilometres increased 11 percent to 74 billion. Changes in weighted activity alone would have increased energy use 16 petajoules. Energy intensity improvements would have produced a 9-petajoule decline in energy use had all other factors remained unchanged. Energy intensity savings are typically achieved in air passenger transport through fleet renewal (e.g., newer aircraft are characterized by more efficient engines and design) and improvements in the match between plane size and load to improve the load factor. However, there were no significant gains achieved in the ratio of passenger-seating utilization to capacity.

6.1.4 Rail

Passenger rail transport accounts for about 0.2 percent of passenger energy use and passenger-kilometres. Between 1990 and 1995, energy use declined more than 50 percent to 2.3 petajoules while passenger-kilometres declined 25 percent. Had only weighted activity changed, energy use would have declined by just over 1 petajoule. Had only intensity changed, energy use would have declined by just less than 2 petajoules. Over this period, the average number of passenger coaches per train declined from 6.1 in 1990 to 5.3 in 1995. Energy intensity improvements were realized as the passenger train system was rationalized, with low capacity and low profit lines being eliminated.

14 In terms of passenger-kilometre activity changes between 1990 and 1995, distance travelled for small cars increased 16 percent, large cars increased 11 percent and light trucks increased 35 percent. In terms of weight, data indicate the trend to smaller cars ended in the late 1980s. Since then, average car weight has increased each year but for two.

15 This is the combined effect of activity and structure, which is sometimes referred to as weighted activity.

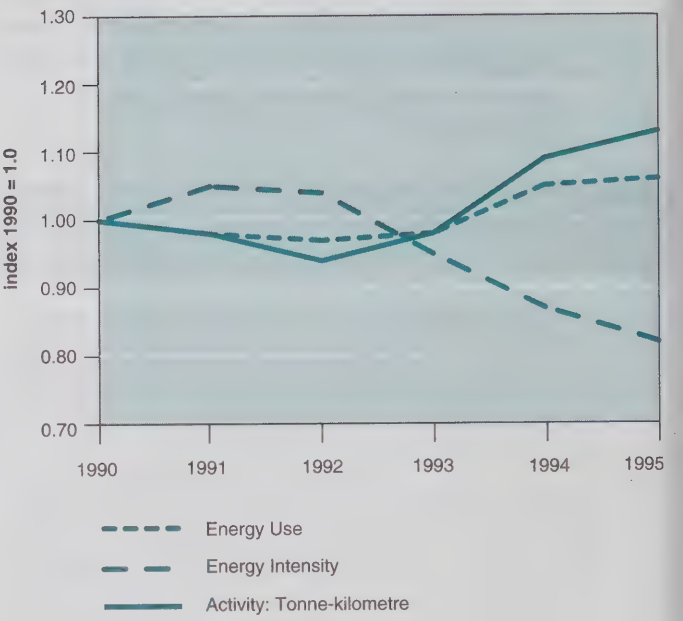
16 As mentioned, this subsection and the next describe their respective contributions to the change in total passenger energy use.

6.2 Evolution of Freight Transportation Energy Use and its Major Determinants[17]

Freight transport energy use is dominated by trucks, which account for nearly 74 percent of freight energy use. Because of the partial truck activity data, trucks account for only 19 percent of tonne-kilometres.[18] Road freight, which serves the market at both ends, is more energy-intensive but more flexible than rail and marine. Rail accounts for 48 percent of tonne-kilometres but only 12 percent of freight transport energy use. Marine accounts for 15 percent of freight energy use but 33 percent of tonne-kilometres.

Freight transportation energy use increased 42 petajoules, or 6 percent (or an average annual rate of 1.3 percent), from 645 petajoules in 1990 to 686 petajoules in 1995. Over the same time, freight activity, measured in tonne-kilometres, increased 13 percent. There were more trucks, and each one in the stock logged more tonne-kilometres per year on average. Figure 6.12 shows the change in freight transport energy use, activity and aggregate intensity from 1990 to 1995.[19]

Figure 6.12
Freight Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



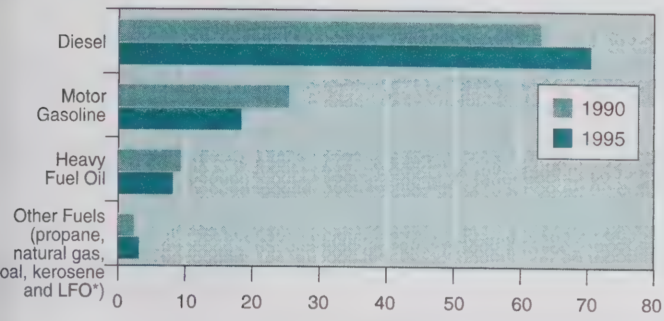
Diesel fuel accounts for 71 percent of freight transport energy use. Its share has risen 8 percentage points between 1990 and 1995. Almost all of this gain has been at the expense of motor gasoline, which declined from 25 to 18 petajoules by 1995. Heavy fuel oil now accounts for 8 percent and propane and natural gas combined account for 3 percent. Both propane and natural gas use showed modest increases. Figure 6.13 shows freight transport fuel share changes between 1990 and 1995.

17 The activity data (tonne-kilometres) underlying the analysis presented in this section are incomplete. As a result, the coverage of energy use is broader than that of tonne-kilometres. The reader should use the freight transportation sector analysis with care.

18 The tonne-kilometre data reported here are for rail, marine and only a portion of truck activity. Road freight activity mostly covers large commercial trucking since it includes only Canadian intercity activity by Canadian-domiciled, for-hire trucking companies with annual revenue of $1 million.

19 There are differences between the aggregate freight energy intensity presented in Figure 6.12 and the factorial intensity presented in Figure 6.15. The aggregate intensity of freight transport is calculated as a weighted average of the energy intensities of each freight mode, which reflect the impact of the mode mix of freight energy use, as well as the impact of the mode specific energy intensities.

igure 6.13
reight Transportation Energy Fuel Shares, 1990 and 1995 (percent)

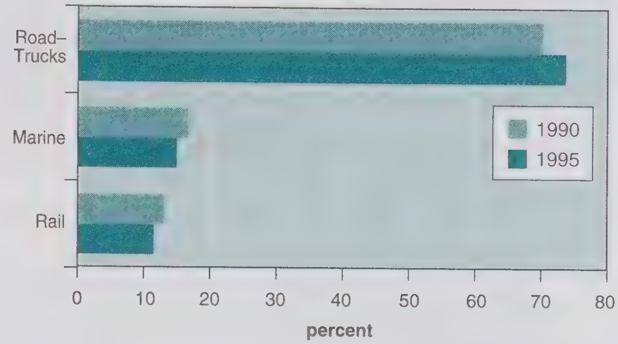


* light fuel oil

The increasing use of diesel was due to an overall growth in the share of large trucks, all of which are diesel fuelled. Large trucks, which represent 46 percent of freight energy and 17 percent of tonne-kilometre activity, accounted for most of the increase in diesel fuel use over the period.[20] Even though total energy use declined within the other two freight truck size categories, fuel switching in favour of diesel permitted increased diesel use in each category. Within the mid-size truck category, which uses mostly diesel and motor gasoline, all fuel switching favoured diesel.[21] For small trucks, diesel use increased marginally.

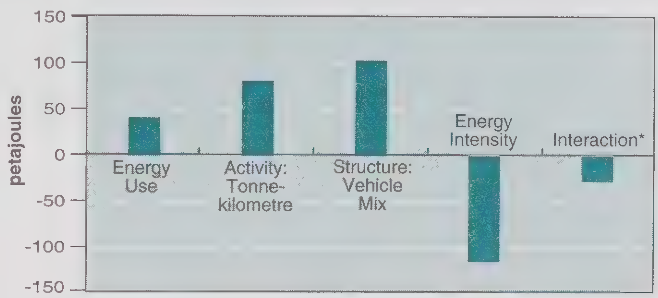
The change in freight transport energy use between 1990 and 1995 shows a preference for road over other modes. Road freight energy use, which is the most energy-intensive mode, increased at the expense of both rail and marine, whose energy use declined.[22] Figure 6.14 illustrates the change in the distribution of freight transportation energy use by mode between 1990 and 1995. The shift toward more flexible road transport is consistent with a move to greater use of "just in time" inventory systems as well as relative price movements in favour of trucking. The decline in rail reflects the weaker growth in bulk-type products such as grains, coal and iron ore as compared to manufactured end products.

Figure 6.14
Freight Transportation Energy Mode Shares, 1990 and 1995 (percent)



Freight energy use increased 42 petajoules between 1990 and 1995. The largest contributing factor to this increase was activity, particularly road freight activity (tonne-kilometres), which increased much more rapidly than rail. As expected, structural shifts were also important, as shown in Figure 6.15.

Figure 6.15
Factors Influencing Growth in Freight Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Earlier in this chapter,[23] the definitional changes in freight activity were reported for trucking and marine. These changes to the historical data also change the result that is obtained for the 1990–1994 period. Using these new data and redoing the analysis for the 1990–1994 period show that structure increases energy use and intensity decreases it. These revised numbers for 1990–1994 are directionally similar to the numbers obtained in this report for the 1990–1995 period.

See footnote 2 for truck size definitions.

The mid-size truck category uses very small amounts of alternative transportation fuels, but these are not identified within the end-use database.

Air freight is not included here because data are limited and poor, though it is recognized as an increasingly important component of high-value freight.

See footnote 3.

Figure 6.15 shows that had all factors except activity remained at their 1990 levels, freight transportation energy use would have increased by 82 petajoules, or 40 petajoules more than the increase observed.[24] The effect of structural shifts away from both marine and rail toward trucks was to increase energy use. Structural shifts alone would have caused an increase of 104 petajoules in freight transport energy use between 1990 and 1995. If energy intensity had not declined, freight transportation energy use would have been 116 petajoules higher in 1995.

24 The change in energy use presented in this figure is the actual change for the freight subsector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis uses a motor gasoline energy equivalency value for all on-road fuels other than diesel.

Chapter 7

An End-Use Perspective on Emissions from Electricity Generation

HIGHLIGHTS

- In an effort to reflect the emissions consequences of electricity generation, an analysis of secondary emission trends was undertaken where electricity is attributed an emissions factor reflecting the average mix of fuels used to generate electricity.
- Emissions under this electricity end-use emissions scenario (ES) were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the no electricity end-use emissions scenario (NES), where there are no carbon dioxide emissions at the end-use level.
- Relative to NES, carbon dioxide emissions from secondary energy use increased at a lower rate in ES. The lower rate in ES was the result of a decline in the carbon dioxide intensity of secondary energy use brought on by a decline in the carbon dioxide intensity of electricity over the period (from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995).
- At the sectoral level, growth in residential emissions over the period declined by 0.4 percent in ES relative to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

The review of changes in carbon dioxide emissions presented in the preceding chapters was undertaken on the basis that end-use electricity consumption does not result in carbon dioxide emissions. In other words, the carbon dioxide intensity of electricity at the end-use level is zero. However, the use of electricity at the end-use level requires the generation of electricity, an activity that produces a significant amount of emissions. In order to give an indication of the emissions consequences of electricity generation, this chapter is devoted to the analysis of emissions trends where electricity is attributed an emissions factor reflecting the average mix of fuels used to generate electricity.

The following acronyms are used to refer to the two emission scenarios discussed throughout the chapter:

NES: No Electricity End-Use Emissions Scenario (i.e., the analysis presented in the preceding chapters where the consumption of electricity at the end-use level does not cause carbon dioxide emissions)

ES: Electricity End-Use Emissions Scenario (i.e., where electricity use at the end-use level is attributed an emissions factor reflecting the average mix of fuels used to generate electricity)

7.1 Emissions from Secondary Energy Use

Table 7.1 presents a comparison of ES with NES for total secondary energy use and each end-use sector. Under NES, emissions from

secondary energy use increased by 15.4 megatonnes (from 303.4 Mt in 1990 to 318.7 Mt in 1995). This represents an increase of 5.1 percent for the period. In ES, emissions from secondary energy use increased by 4.1 percent, or 16.1 megatonnes (from 389.1 Mt in 1990 to 405.1 Mt in 1995).

Relative to NES, emissions are 28 percent greater in 1990 and 27 percent higher in 1995 under ES. The difference in the order of magnitude between scenarios is due to the fact that electricity, which accounts for a significant portion of energy use in the residential, commercial and industrial sectors (i.e., 35, 44 and 26 percent, respectively, in 1995), has a carbon dioxide intensity of zero under NES compared to ES, where the average carbon dioxide intensity of electricity is significant (i.e., 12 percent and 7 percent more intensive than natural gas in 1990 and 1995, respectively). Although this explains the difference in magnitude between the two scenarios, it does not provide insight into the difference in the growth of emissions between NES and ES.

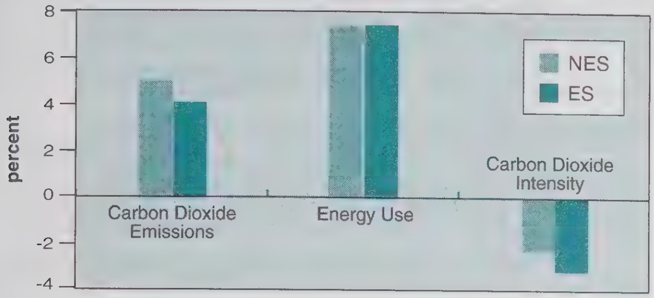
The growth in emissions over the period is stronger in NES than ES (i.e., 5.1 percent in NES versus 4.1 percent in ES) because of a decline in the carbon dioxide intensity of electricity use in ES. At the secondary energy use level, the share of electricity to total energy in 1995 (22.6 percent) barely changed relative to the 1990 share (22.5 percent). As a result, the impact on emissions due to fuel switching to or from electricity in either NES or ES was minimal. However, in ES, the carbon dioxide intensity of electricity (which was zero for both 1990 and 1995 in NES) declined from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995. This decline contributed to a reduction in the carbon dioxide intensity of secondary energy use and subsequently to a lower growth in emissions relative to NES. The decline in the carbon dioxide intensity of electricity was due to a shift in fuels used to produce electricity, from coal and heavy fuel oil to natural gas and nuclear.

Figure 7.1 shows the change in secondary energy emissions, energy use and carbon dioxide intensity for both NES and ES. Given that the change in energy use is the same in both scenarios, the difference in the change of emissions between the two scenarios can be explained entirely by the respective changes in carbon dioxide intensity. The change in carbon dioxide intensity over the period from 1990 to 1995 is -3.2 percent in ES compared to -2.3 percent in NES over the same period.

Table 7.1
Secondary Energy Carbon Dioxide Emissions, 1990 and 1995 (megatonnes)

	No Electricity End-Use Emissions Scenario			Electricity End-Use Emissions Scenario		
	1990	1995	1995 less 1990	1990	1995	1995 less 1990
Residential	42.1	43.4	1.3	68.5	68.2	-0.3
Commercial	26.7	28.1	1.4	47.9	50.0	2.1
Industrial	96.4	98.9	2.4	132.5	136.7	4.2
Transportation	126.8	136.7	10.0	126.9	136.9	9.9
Agriculture	11.3	11.6	0.3	13.3	13.4	0.1
Total	303.4	318.7	15.4	389.1	405.1	16.1

Figure 7.1
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Secondary Energy Use, 1990–1995 (percent)



NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

The rest of this chapter will examine the results of the analysis for the residential, commercial and industrial sectors. The results for the transportation sector are not discussed as they are similar in both scenarios given that electricity use in this sector is negligible.

7.1.1 Residential sector

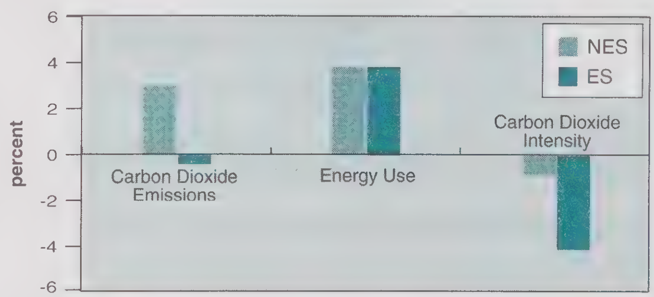
Residential sector emissions are 57 percent higher in 1995 in ES as compared to NES. The difference reflects the importance of electricity as an energy source for the residential sector (accounting for some 34 percent of energy use) and that it has a carbon dioxide intensity of zero under NES compared to ES where the average carbon dioxide intensity of electricity is more intensive than natural gas—the dominant residential energy source.

Under NES, residential emissions increased by 3.0 percent over the period from 1990 to 1995. However, under ES, emissions declined by 0.4 percent. The difference in the growth of emissions between the two scenarios can be attributed to changes in electricity use and its associated carbon dioxide intensity.

Although the absolute level of residential electricity use increased by 1 percent (from 471.5 petajoules to 476.5 petajoules) over the period, the share of electricity to total residential energy use decreased by 1 percentage point (from 35.6 percent to 34.6 percent). This decrease in the share of electricity use in favour of natural gas—the only fuel to experience an increase in share of total residential energy—contributed to an increase in emissions in NES. In ES, however, the combination of the shift from electricity to natural gas with the decline in the carbon dioxide intensity of electricity as well as the growth in residential energy use (3.9 percent) contributed to a decrease in the growth of emissions.

Figure 7.2 illustrates the change in residential emissions according to changes in energy use and carbon dioxide intensity for both scenarios. As shown in Figure 7.2, the change in carbon dioxide intensity over the period from 1990 to 1995 is significantly greater in ES (-4.1 percent) compared to NES (-0.8 percent).

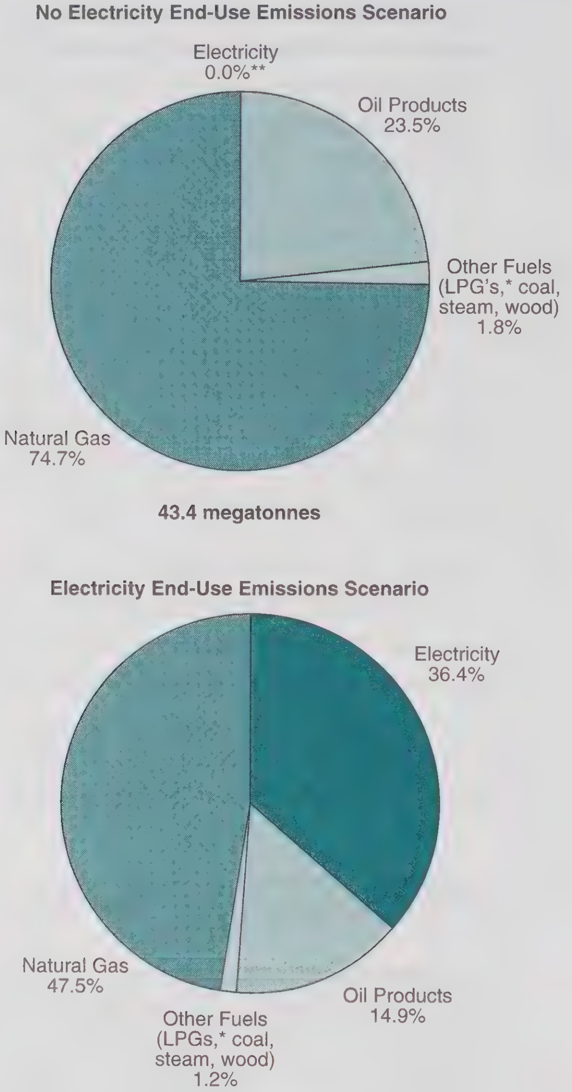
Figure 7.2
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)



NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

In NES, 74.7 percent of residential emissions in 1995 were attributed to the use of natural gas. However, under ES, the share of emissions from natural gas is reduced to 47.5 percent. Moreover, electricity captures 36.4 percent of residential sector emissions. Figure 7.3 illustrates the distribution of residential emissions under the two scenarios for 1995.

Figure 7.3
Residential Carbon Dioxide Emissions by Fuel, 1995 (percent)

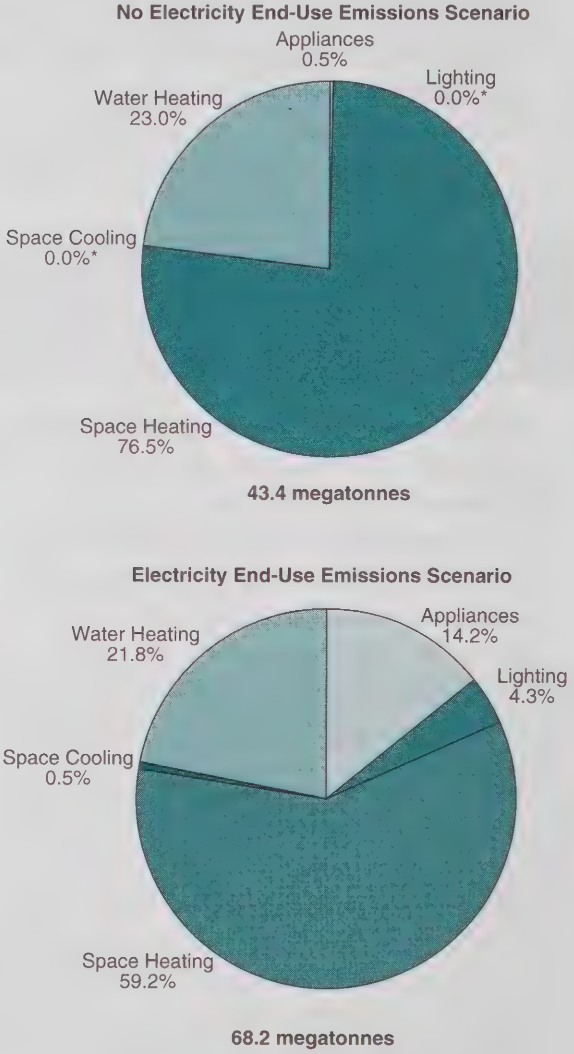


* liquefied petroleum gases
**Amount too small to be expressed at one decimal

Figure 7.4 presents the 1995 distribution of residential emissions according to end use. Under NES, space heating and water heating account for virtually all of the end-use emissions (76.5 percent and 23 percent, respectively). However, under ES, appliances, lighting, and space cooling capture 19 percent of residential emissions—almost completely at the expense of space heating. This change is due to the fact that appliances, lighting and space cooling are almost entirely (i.e., 98 percent) electricity-based end uses compared to space heating where the share of electricity, in percentage terms (16 percent), is less than one half of the residential electricity share (34 percent). The share of water heating is marginally less

in ES because the share of electricity to total water-heating energy (33 percent) is also marginally less, on a percentage basis, than the share of electricity to total residential energy.

Figure 7.4
Residential Carbon Dioxide Emissions by End Use, 1995 (percent)



* Amount too small to be expressed at one decimal

7.1.2 Commercial sector

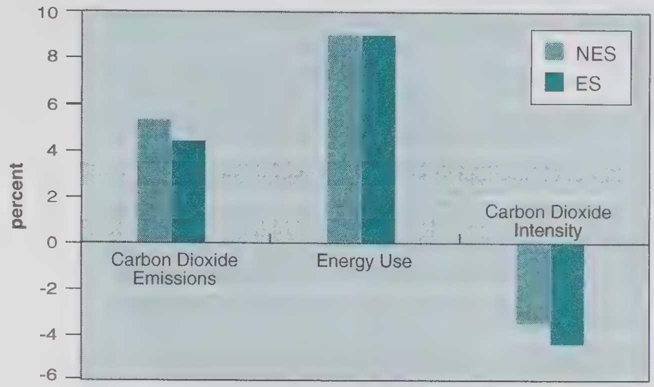
The attribution of carbon dioxide intensities to electricity led to an increase in commercial sector emissions in 1995 by 78 percent relative to NES. This attribution also had the effect of reducing growth in emissions. Under NES, commercial emissions increased by 5.4 percent from 1990 to 1995. However, under ES, emissions increased by 4.4 percent.

The share of electricity to total commercial energy use increased by almost 1 percentage point over the period. In NES, this shift to electricity from petroleum products contributed to a decrease in the carbon dioxide intensity of commercial energy use, thereby partially offsetting emissions related to growth in commercial energy use of 9 percent. In ES, the shift to electricity also exerted downward pressure on the growth of emissions because the carbon dioxide intensity of electricity is less than that of petroleum products.

Over the period, the decline in the carbon dioxide intensity of electricity under ES also contributed to the reduction in the growth of emissions. The end result is that the growth of commercial sector emissions from 1990 to 1995 is almost 1 percentage point less in ES relative to NES.

Figure 7.5 illustrates the change in commercial emissions according to changes in energy use and carbon dioxide intensity for both scenarios. The change in carbon dioxide intensity from 1990 to 1995 is -4.4 percent in ES compared to -3.5 percent in NES.

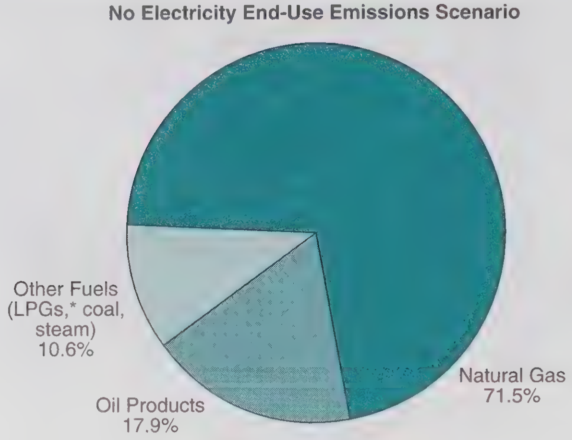
Figure 7.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

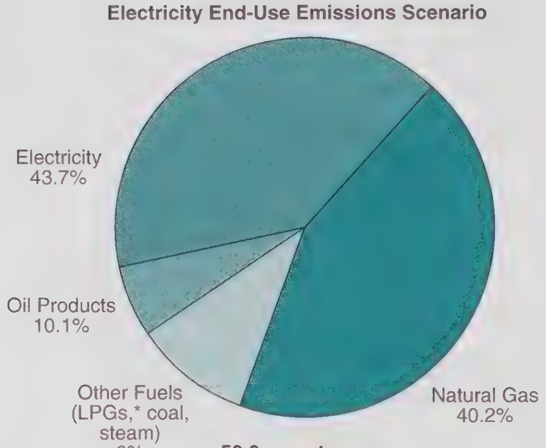


NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

Under NES, the source of commercial sector emissions is dominated by the use of natural gas. In 1995, 71.5 percent of emissions in NES were attributed to natural gas. However, under ES, natural gas took a back seat to electricity as the principal source of commercial sector emissions. Under ES, natural gas accounts for 40.2 percent of sector emissions in 1995, whereas electricity appropriates 43.7 percent. Figure 7.6 illustrates distribution of commercial emissions under the two scenarios for 1995.

Figure 7.6
Commercial Carbon Dioxide Emissions by Fuel, 1995 (percent)



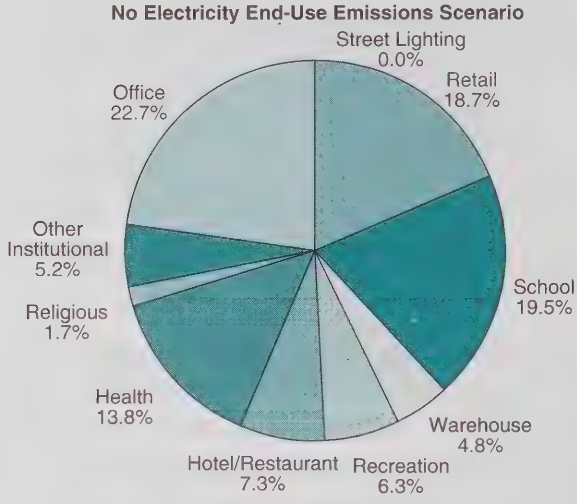


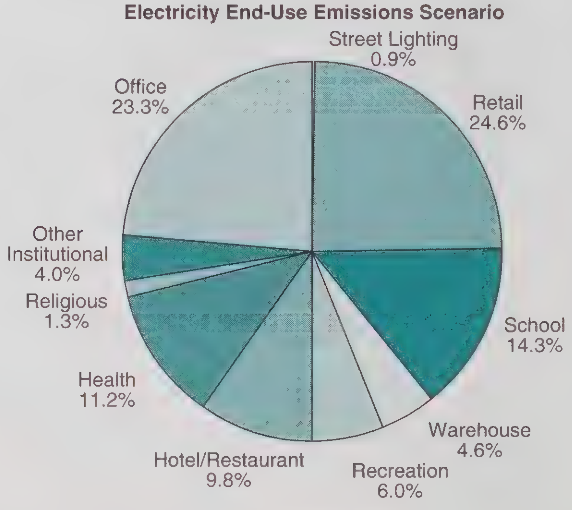
* liquefied petroleum gases

Figure 7.7 presents the 1995 distribution of commercial sector emissions according to building type for both NES and ES. The most significant differences between the two scenarios involved the following subsectors: retail, hotel and restaurant, schools, and health. Relative to NES, emissions from retail buildings increased by 6 percentage points and that from hotels and restaurants increased by almost 3 percentage points in ES. These increases are explained by the fact that these two building types have significant electricity loads. In fact, of all commercial building types, retail buildings maintain the largest share of electricity use for motive power (43 percent), space cooling (37 percent), and lighting (32 percent), and are third in terms of auxiliary equipment (25 percent) and heating (20 percent). Similarly, hotels and restaurants maintain the largest commercial electricity share for auxiliary equipment (35 percent) and together are third for space cooling (22 percent).

Conversely, emissions from educational and health facilities decreased (about 5 and almost 3 percentage points, respectively) over the period. These decreases are due to the fact that their shares of electricity, in percentage terms, are less than the commercial sector average.

Figure 7.7
Commercial Carbon Dioxide Emissions by Building Type,* 1995 (percent)





* including street lighting

7.1.3 Industrial sector

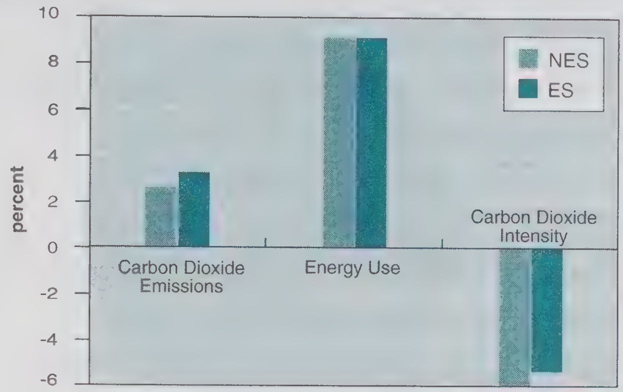
Industrial sector emissions in 1995 were 39 percent greater in ES relative to NES, and unlike the residential and commercial sectors, the growth in emissions over the period from 1990 to 1995 was stronger in ES relative to NES (i.e., 3.2 percent in ES versus 2.5 percent in NES).

As was the case in the commercial sector, the share of electricity to total industrial energy use increased by almost 1 percentage point over the period. However, the share of biomass increased by 2.5 percent, which, combined with the shift to electricity away from carbon intensive fuels, contributed to a decrease in the overall industrial carbon dioxide intensity of 6 percent in NES. This decrease was not enough to offset emissions associated with growth in industrial energy use of over 9 percent.

In ES, the growth in electricity use (12.7 percent) overpowered the decline in the carbon dioxide intensity of electricity (7 percent), thus resulting in a smaller reduction in the overall industrial carbon dioxide intensity relative to NES. Over the period, the net effect was such that the growth of industrial emissions was 0.7 percentage points greater in ES relative to NES.

Figure 7.8 illustrates the change in industrial emissions over the period from 1990 to 1995 according to changes in energy use and carbon dioxide intensity for both scenarios. The difference in the growth in emissions between scenarios is, as discussed, due to the change in carbon dioxide intensity, which declined by 5.4 percent in ES compared to a decline of 6.0 percent in NES.

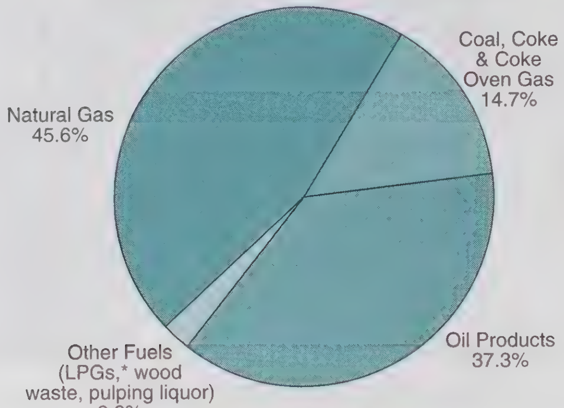
Figure 7.8
Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Industrial Sector, 1990–1995 (percent)

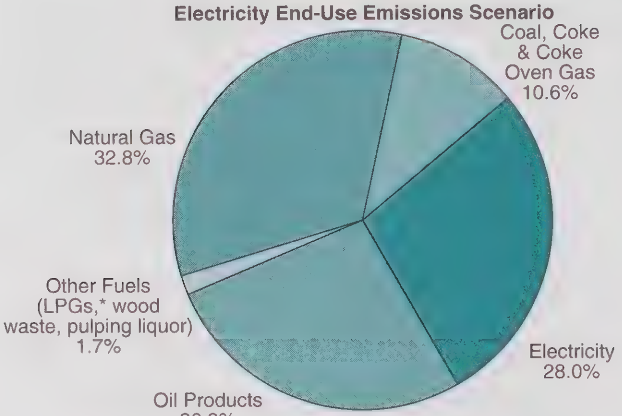


NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

Figure 7.9 illustrates distribution of industrial sector emissions under the two scenarios for 1995. Under NES, 83 percent of industrial sector emissions in 1995 are attributed to the use of natural gas and oil products (45.6 percent and 37.3 percent, respectively). However, in ES, natural gas and oil products accounted for 60 percent of sector emissions in 1995 (i.e., 32.8 percent and 26.9 percent, respectively). The share of industrial sector emissions from electricity in ES (28.0 percent) exceeds the share of emissions from oil products by 1 percentage point.

Figure 7.9
Industrial Carbon Dioxide Emissions by Fuel, 1995 (percent)





* liquefied petroleum gases

Figure 7.10 presents the 1995 distribution of industrial sector emissions according to industry for both NES and ES. The most significant differences between the two scenarios are found in pulp and paper, smelting and refining, petroleum refining, and iron and steel. Relative to NES, emissions from smelting and refining increased by almost 6 percentage points, and emissions from pulp and paper increased by almost 5 percentage points.

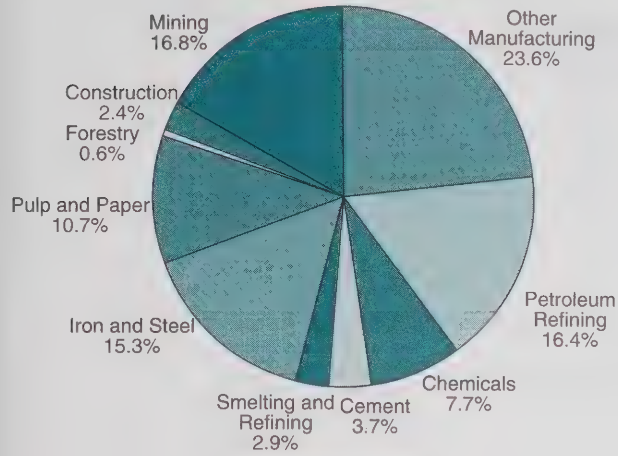
The increase in emissions associated with smelting and refining can be attributed to its share of electricity use to total energy use (79 percent), which far exceeds the average for the industrial sector. Electricity use in this industry is driven by electricity requirements for aluminum production.

The increase in emissions in the pulp and paper industry can be explained by the use of electricity and biomass. Although the share of electricity use in the pulp and paper industry (23 percent) is less than the industrial average (26 percent), it accounts for 52 percent of non-biomass energy use. In light of the fact that biomass accounts for 56 percent of pulp and paper energy use and that biomass has a carbon dioxide intensity of zero, electricity use becomes a significant contributor to emissions generated from this industry under ES.

On the other hand, emissions from petroleum refining decreased by almost 4 percentage points, and emissions from iron and steel decreased by 3 percentage points. These decreases are the result of their relatively small electricity shares (i.e., 7 percent for petroleum refining and 13 percent for iron and steel) compared to the industrial average.

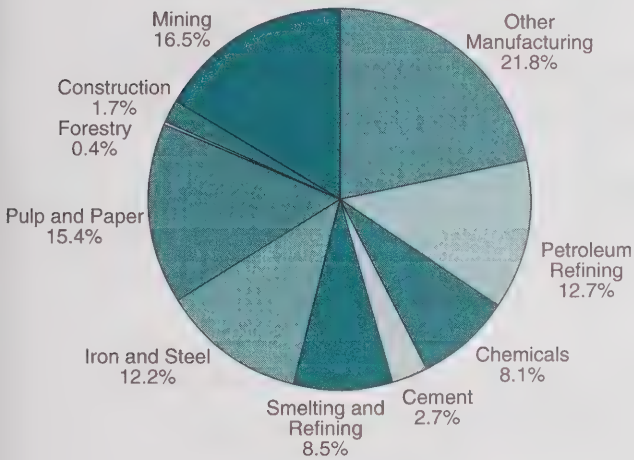
igure 7.10
ndustrial Carbon Dioxide Emissions by Industry, 1995 (percent)

No Electricity End-Use Emissions Scenario



96.4 megatonnes

Electricity End-Use Emissions Scenario



98.9 megatonnes

7.2 Conclusion

Carbon dioxide emissions under a scenario where electricity was attributed an emissions factor reflecting the average mix of fuels used to generate electricity—ES—were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the scenario where electricity has a zero carbon dioxide intensity at the end-use level—NES. However, relative to NES, carbon dioxide emissions at the secondary energy use level increased at a lower rate in ES. The lower rate in ES was the result of a stronger decline in the carbon dioxide intensity of secondary energy brought on by the incremental decline in the carbon dioxide intensity of electricity over the period.

At the secondary energy use level, the change in the share of electricity to total energy was negligible over the period. As a result, there was a minimal effect on emissions due to fuel switching to or from electricity in either NES or ES. However, at the end-use sector level, fuel switching to and from electricity influenced the growth in emissions over the period from 1990 to 1995.

At the sector level, growth in residential emissions over the period declined by 0.4 percent in ES relative to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

Data Presented in Report

Table A-2.1
Secondary Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Oil Products	40.0	38.2
Natural Gas	26.1	27.1
Electricity	22.4	22.6
Other Fuels*	11.5	12.1

* Includes liquefied petroleum gases, coal, coke and coke oven gases, steam, biomass

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.1
Distribution of Households by Type of Dwelling, 1995 (percent)

Housing Types	1995
Mobile Homes	2.0
Apartments	32.3
Single-Attached	10.2
Single-Detached	55.5

Source: • Statistics Canada, *Household Facilities and Equipment*, 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1995.

TABLE A-3.2
Distribution of Residential Energy Use by End Use, 1995 (percent)

End Uses	1995
Space Cooling	0.5
Water Heating	20.8
Appliances	13.5
Space Heating	61.1
Lighting	4.1

Sources:
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario, October 1995.
- Statistics Canada, *Household Facilities and Equipment*, 1995 (Cat. 64-202), Annual, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.

TABLE A-3.3
Residential Carbon Dioxide Emissions by End Use, 1990 and 1995 (percent)

End Uses	1990	1995
Space Heating	78.5	76.5
Water Heating	21.1	23.0
Appliances	0.4	0.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, Residential End-use Model, Ottawa, Ontario, October 1995.

TABLE A-3.4
Residential Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.96	0.95	1.05	1.06	1.03
Energy Use	1.00	0.97	0.98	1.05	1.06	1.04
Carbon Dioxide Intensity	1.00	0.98	0.97	1.00	1.00	0.99

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-3.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	3.0
Energy Use	3.9
Carbon Dioxide Intensity	-0.8

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-3.6
Residential Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Natural Gas	41.7	47.7
Electricity	35.6	34.6
Oil	14.1	10.1
Other Fuels*	8.6	7.6

* Includes liquefied petroleum gases, coal, steam, wood

Source:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.7
Residential Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Weather	1.00	1.00	1.03	1.04	1.03	1.03
Weather-Adjusted Energy Intensity	1.00	0.94	0.91	0.94	0.95	0.91
Energy Use	1.00	0.97	0.98	1.05	1.06	1.04
Energy Intensity	1.00	0.95	0.94	0.98	0.98	0.93
Activity: Households	1.00	1.03	1.05	1.07	1.08	1.10

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, various issues (Cat. 64-202), Annual, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-3.8
Factors Influencing Growth in Residential Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	51.41
Activity: Households	134.79
Weather	40.19
Structure: End-Use Mix	15.83
Energy Intensity	-125.27
Interaction	-14.07

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.9
Factors Influencing Growth in Residential Space-Heating Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	20.80
Activity: Households	83.43
Weather	40.19
Energy Intensity	-95.39
Interaction	-7.44

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-3.10
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1995 (thousands of units)

Efficiencies	1990	1995
Normal Efficiency	87.2	0.0
Mid-Efficiency	22.0	91.9
High-Efficiency	29.9	56.8

Source:
- Canadian Gas Association, *Canadian Gas Facts 1996*, North York, Ontario, 1996.

TABLE A-3.11
Housing Stock by Vintage, 1990 and 1995 (percent)

Vintages	1990	1995
Pre-1946	21.9	19.1
1946-1960	14.6	13.0
1961-1977	35.3	31.7
1978-1983	12.5	11.6
Post 1983	15.7	24.6

Sources:
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.

TABLE A-3.12
Average Heated Living Area per Dwelling by Vintage (square feet)

Vintages	Average Heated Area
Pre-1941	1299
1941-1960	1174
1961-1977	1287
1978-1982	1374
1983-1993	1535
1994	1732

Sources:
- Natural Resources Canada, *1993 Survey of Household Energy Use, National Results*, Ottawa, Ontario, November 1994.
- Natural Resources Canada, *Survey of Houses Built in Canada in 1994*, Ottawa, Ontario, October *1996*.

TABLE A-3.13
Factors Influencing Growth in Residential Appliance Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	6.20
Activity: Households	18.28
Appliance Penetration	13.91
Energy Intensity	-23.18
Interaction	-2.81

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, Residential End-use Model, Ottawa, Ontario, October 1995.

TABLE A-3.14
Penetration Rates for Household Appliances, 1990 and 1995 (average number per household)

Appliances	1990	1995
Refrigerators	1.18	1.19
Ranges	0.98	0.99
Microwave Ovens	0.68	0.83
Video Cassette Recorders	0.66	0.82
Clothes Washers	0.78	0.79
Clothes Dryers	0.73	0.76
Freezers	0.53	0.57
Dishwashers	0.42	0.47
Compact Disc Players	0.15	0.47
Home Computers	0.16	0.29

Source: • Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.

TABLE A-3.15
Energy Efficiency Trends of New Appliances, 1990 and 1995 (kWh per year)

Appliances	1990	1995
Clothes Washers	1200	1050
Clothes Dryers	1092	744
Refrigerators	1020	660
Dishwashers	1000	700
Ranges	732	768
Freezers	528	396

Source: • Natural Resources Canada, *EnerGuide Directories* 1990 and 1995, Ottawa, Ontario.

TABLE A-4.1
Distribution of Commercial Energy Use and Activity by Building Type, 1995 (percent)
Energy Use

Building Types	1995
Retail	25.1
Office	23.5
School	14.4
Health	11.1
Hotel/Restaurant	9.9
Recreation	6.0
Warehouse	4.7
Other Institutional	4.0
Religious	1.3

Activity

Building Types	1995
Retail	23.5
Office	26.0
School	15.2
Health	7.1
Hotel/Restaurant	6.6
Recreation	6.3
Warehouse	9.0
Other Institutional	4.5
Religious	1.8

Sources:
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.

TABLE A-4.2
Commercial Carbon Dioxide Emissions by Building Type, 1990 and 1995 (percent)

Building Types	1990	1995
Retail	19.3	18.7
Office	21.5	22.7
School	19.9	19.5
Health	14.0	13.8
Hotel/Restaurant	7.1	7.3
Recreation	5.9	6.3
Warehouse	5.4	4.8
Other Institutional	5.0	5.2
Religious	1.9	1.7

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-4.3
Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	1.00	1.03	1.00	1.05
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09
Carbon Dioxide Intensity	1.00	0.96	0.97	0.97	0.95	0.97

Sources:
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-4.4
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	5.3
Energy Use	9.2
Carbon Dioxide Intensity	-3.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-4.5
Commercial Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Electricity	43.9	44.5
Natural Gas	42.1	43.2
Oil Products	8.3	7.3
Other Fuels*	5.7	5.0

* Includes liquefied petroleum gases, coal, steam

Source:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-4.6
Commercial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Weather	1.00	1.01	1.00	1.02	1.01	1.01
Weather-Adjusted Energy Intensity	1.00	0.98	0.98	0.98	0.97	0.97
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09
Activity: Floor Space	1.00	1.03	1.05	1.07	1.08	1.10
Energy Intensity	1.00	0.98	0.98	1.00	0.98	0.99

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.

TABLE A-4.7
Factors Influencing Growth in Commercial Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	78.27
Activity: Floor Space	87.71
Weather	11.52
Structure: Building Type	3.32
Energy Intensity	-22.65
Interaction	-1.33

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-4.8
Changes in Building Type Shares of Commercial Activity, 1990–1995 (percentage points)

Factors	1990–1995
Health	-0.03
Hotel/Restaurant	-0.03
Retail	-1.14
Recreation	0.41
School	0.21
Office	1.77
Other Institutional	0.27
Religious	-0.13
Warehouse	-1.32

Source:
- Informetrica Limited *Historical Estimates of Commercial Floor Space, 1995 Database Update,* Ottawa, Ontario, September 15, 1996.

TABLE A-5.1
Distribution of Industrial Energy Use and Activity by Industry, 1995 (percent)

Energy Use

Sectors	1995
Pulp and Paper	30.2
Mining	12.7
Petroleum Refining	10.5
Iron and Steel	8.3
Chemicals	7.6
Smelting and Refining	7.4
Cement	2.0
Construction	1.2
Forestry	0.3
Other Manufacturing	19.8

Activity

Sectors	1995
Pulp and Paper	5.9
Mining	15.4
Petroleum Refining	1.4
Iron and Steel	1.7
Chemicals	1.8
Smelting and Refining	1.8
Cement	0.2
Construction	16.6
Forestry	2.3
Other Manufacturing	52.9

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.2
Industrial Carbon Dioxide Emissions by Industry, 1990 and 1995 (percent)

Sectors	1990	1995
Pulp and Paper	12.7	10.7
Mining	10.6	16.8
Petroleum Refining	17.7	16.4
Iron and Steel	14.8	15.3
Chemicals	8.1	7.7
Smelting and Refining	3.6	2.9
Cement	3.9	3.7
Construction	3.2	2.4
Forestry	1.2	0.6
Other Manufacturing	24.1	23.6

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-5.3
Industrial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	0.96	0.98	0.98	1.03
Energy Use	1.00	0.99	0.99	1.01	1.04	1.09
Carbon Dioxide Intensity	1.00	0.98	0.96	0.97	0.94	0.94

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-5.4
Industrial Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Coal, Coke and Coke Oven Gas	6.6	5.9
Oil Products	21.7	19.8
Electricity	24.7	25.5
Natural Gas	32.3	31.6
Other Fuels*	14.7	17.2

* Includes liquefied petroleum gases, wood waste, pulping liquor

Source:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-5.5
Industrial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.99	0.99	1.01	1.04	1.09
Energy Intensity	1.00	1.06	1.06	1.05	1.02	1.03
Activity: Gross Domestic Product	1.00	0.94	0.93	0.96	1.02	1.06

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.6
Factors Influencing Growth in Industrial Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	240.65
Activity: GDP	156.50
Structure: Sector Mix	68.28
Energy Intensity	11.25
Interaction	4.61

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.7
Changes in Sectoral Shares of Industrial Activity, 1990–1995 (percentage points)

Sectors	1990–1995
Cement	-0.06
Petroleum Refining	-0.05
Pulp and Paper	0.01
Iron and Steel	0.07
Chemicals	-0.18
Smelting and Refining	0.31
Mining	2.15
Other Manufacturing	2.90
Forestry	0.08
Construction	-5.22

Source: • Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-6.1
Distribution of Passenger Transportation Energy Use and Activity by Mode, 1995 (percent)

Energy Use

Modes	1995
Road – Light Vehicles	83.9
Aviation	14.2
Road – Buses	1.5
Rail	0.4

Activity

Modes	1995
Road – Light Vehicles	86.3
Aviation	11.8
Road – Buses	1.7
Rail	0.2

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.

TABLE A-6.2
Distribution of Freight Transportation Energy Use and Activity by Mode, 1995 (percent)

Energy Use

Modes	1995
Road – Trucks	73.7
Marine	14.8
Rail	11.5

Activity

Modes	1995
Road – Trucks	19.0
Marine	32.6
Rail	48.4

Sources:
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-6.3
Transportation Carbon Dioxide Emissions by Mode, 1990 and 1995 (percent)

Modes	1990	1995
Road - Light Vehicles	52.8	54.2
Road - Trucks	24.8	25.7
Aviation	10.4	9.6
Marine	6.1	5.4
Rail	5.0	4.2
Road - Buses	0.9	0.9

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-6.4
Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	0.99	1.01	1.06	1.08
Energy Use	1.00	0.97	0.99	1.01	1.06	1.08
Carbon Dioxide Intensity	1.00	1.00	1.00	1.00	1.00	1.00

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-6.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	7.9
Energy Use	8.0
Carbon Dioxide Intensity	-0.1

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-6.6
Passenger Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.96	1.00	1.02	1.07	1.09
Energy Intensity	1.00	0.99	0.99	0.97	0.97	0.95
Activity: Passenger-Kilometre	1.00	0.97	1.02	1.06	1.11	1.15

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.7
Passenger Transportation Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Motor Gasoline	80.1	80.7
Aviation Turbo Fuel	15.5	14.2
Diesel	3.0	3.1
ATFs*	1.4	2.0

* Alternative transportation fuels, includes propane, natural gas and electricity

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.8
Passenger Transportation Energy Mode Shares, 1990 and 1995 (percent)

Modes	1990	1995
Road – Light Vehicles	82.4	84.0
Aviation	15.5	14.2
Road – Buses	1.7	1.6
Rail	0.4	0.2

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa,
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.9
Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	104.87
Activity: Passenger-Kilometre	175.57
Structure: Vehicle Mix	1.61
Energy Intensity	-55.50
Interaction	-9.60

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.10
Factors Influencing Growth in Light-Vehicle Passenger Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	106.24
Activity: Passenger-Kilometre	166.26
Structure: Vehicle Mix	8.81
Energy Intensity	-59.73
Interaction	-8.09

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.11
Trends in Car Fuel Economy, 1978–1995 (L/100 km)

Years	All Cars	New Cars
1978	16.72	14.82
1979	16.39	14.14
1980	15.97	13.13
1981	15.50	12.40
1982	14.93	10.29
1983	14.22	9.86
1984	13.52	10.07
1985	12.79	9.87
1986	12.20	10.08
1987	11.71	10.22
1988	11.26	9.87
1989	10.95	10.18
1990	10.73	10.32
1991	10.57	10.27
1992	10.42	9.95
1993	10.32	10.07
1994	10.24	9.94
1995	10.17	9.90

Sources:
- DesRosiers Automotive Consultants Inc., *Canadian Light Vehicles in Operation Census*, Toronto, Ontario.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Transport Canada Fuel Consumption Guide, all years, Ottawa, Ontario.
- Crain Communication, Automotive News Annual Market Data Books, Detroit, MI, 1978-1995.

TABLE A-6.12
Freight Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.98	0.97	0.98	1.05	1.06
Energy Intensity	1.00	1.05	1.04	0.95	0.87	0.82
Activity: Tonne-Kilometre	1.00	0.98	0.94	0.98	1.09	1.13

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-6.13
Freight Transportation Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Diesel	63.0	70.5
Motor Gasoline	25.4	18.3
Heavy Fuel Oil	9.3	8.1
Other Fuels*	2.3	3.1

* Includes propane, natural gas, coal, kerosene and light fuel oil

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.14
Freight Transportation Energy Mode Shares, 1990 and 1995 (percent)

Modes	1990	1995
Road – Trucks	70.2	73.7
Marine	16.7	14.9
Rail	13.1	11.4

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.15
Factors Influencing Growth in Freight Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	41.55
Activity: Tonne-Kilometre	81.98
Structure: Vehicle Mix	104.26
Energy Intensity	-115.89
Interaction	-28.09

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-7.1
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Secondary Energy Use, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	5.1	4.1
Energy Use	7.5	7.5
Carbon Dioxide Intensity	-2.3	-3.2

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.2
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	3.0	-0.4
Energy Use	3.9	3.9
Carbon Dioxide Intensity	-0.8	-4.1

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.3
Residential Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	--	36.4
Oil Products	23.5	14.9
Natural Gas	74.7	47.5
Other Fuels*	1.8	1.2

-- Amount too small to be expressed at one decimal

* Includes liquefied petroleum gases, coal, steam, wood

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.4
Residential Carbon Dioxide Emissions by End Use, 1995 (percent)

End Uses	NES	ES
Space Heating	76.5	59.2
Space Cooling	--	0.5
Water Heating	23.0	21.8
Appliances	0.5	14.2
Lighting	--	4.3

-- Amount too small to be expressed at one decimal

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.

TABLE A-7.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	5.4	4.4
Energy Use	9.0	9.0
Carbon Dioxide Intensity	-3.5	-4.4

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.6
Commercial Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	0.0	43.7
Oil Products	17.9	10.1
Natural Gas	71.5	40.2
Other Fuels*	10.6	6.0

* Includes liquefied petroleum gases, coal, steam

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.7
Commercial Carbon Dioxide Emissions by Building Type, 1995 (percent)

Building Types	NES	ES
School	19.5	14.3
Warehouse	4.8	4.6
Recreation	6.3	6.0
Hotel/Restaurant	7.3	9.8
Health	13.8	11.2
Religious	1.7	1.3
Other Institutional	5.2	4.0
Office	22.7	23.3
Retail	18.7	24.6
Street Lighting	0.0	0.9

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.

TABLE A-7.8
Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Industrial Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	2.5	3.2
Energy Use	9.1	9.1
Carbon Dioxide Intensity	-6.0	-5.4

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.9
Industrial Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	0.0	28.0
Oil Products	37.3	26.9
Natural Gas	45.6	32.8
Coal, Coke and Coke Oven Gas	14.7	10.6
Other Fuels*	2.3	1.7

*Includes liquefied petroleum gases, wood waste, pulping liquor

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.10
Industrial Carbon Dioxide Emissions by Industry, 1995 (percent)

Sectors	NES	ES
Other Manufacturing	23.6	21.8
Petroleum Refining	16.4	12.7
Chemicals	7.7	8.1
Cement	3.7	2.7
Smelting and Refining	2.9	8.5
Iron and Steel	15.3	12.2
Pulp and Paper	10.7	15.4
Forestry	0.6	0.4
Construction	2.4	1.7
Mining	16.8	16.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

Methodology and Data Sources for the Energy Use Factorization Analysis

1 Introduction

This appendix briefly describes the key elements of methodology used in this study to analyse secondary energy end-use trends in the Canadian economy as a whole and in each of the four end-use sectors. Four important objectives motivated the choice of methodology:[1]

- Interpretation of the index is straightforward.
- The same index can be applied to all sectors and subsectors so that all can be interpreted similarly.
- Data are available with which to calculate the indexes.
- The index is theoretically sound.

In the simplest of terms, an energy efficiency index is a statistical indicator that measures energy use, taking account of changes in energy intensity, structural influences, and economic or physical activity. Such indicators can be applied to measure energy consumption at the economy-wide level and in individual sectors (e.g., transportation, commercial), industries (e.g., forestry, pulp and paper manufacturing) and specific end uses (e.g., space heating, refrigeration). The basic formulation used here, a Laspeyres factorization method, has been used extensively in international comparisons of energy use.

2 The Factorization Method

Although the ratio of energy to gross domestic product (GDP) provides a broad indicator of overall energy intensity in the economy, many researchers have pointed out that changes to this indicator result from both structural changes in the economy as well as technical efficiency improvements. For example, because the industrial sector is more energy-intensive than the other sectors, it would contribute to a lower energy/GDP ratio if its energy use declined in relation to GDP, even if industrial energy intensity remained unchanged.

1 B. Jenness, M. Haney and A. Storey, *Energy Efficiency Indicators: Conceptual Framework and Data Sources,* prepared by Informetrica Limited for Natural Resources Canada, March 31, 1995.

The development of the formulas for the indexes in the following sections is based on the following "identity":

$$E = A\frac{E}{A} = A\Omega$$

where “E” is energy use, and “A” is the level of activity. The quantity Ω is the intensity of energy use per unit of activity.

The following section develops indexes that characterize different influences on the movements in aggregate energy use. For an energy-consuming sector composed of several subsectors (or "outlets"), movements in aggregate energy can be due to changes in the mix of activity of its subsectors or changes in the intensity of energy use of its subsectors. The relationship between aggregate energy use in a sector and those of its subsectors is:

$$E = \sum_i E_i = \sum_i A_i \Omega_i$$

where the subscript "i" denotes the "ith" subsector.

We are interested in separating aggregate activity effects from activity mix effects between subsectors. Accordingly, we rewrite the above equation as:

$$E = A\sum_i a_i \Omega_i$$

where "a_i" is the activity share of the “ith” sub-sector:

$$a_i = \frac{A_i}{A}$$

Our basic energy identity is then:

$$E = A\sum_i a_i \Omega_i$$

Since we will be developing formulas for indexes, a notation is needed to denote time. The convention used in the following sections is to subscript a quantity with "o" to denote the base-period value. The absence of an "o" subscript will always denote the current time period. Thus, for example, the above identity in index form becomes:

$$\frac{E}{E_o} = \frac{A\sum_i a_i \Omega_i}{A_o \sum_i a_{io} \Omega_{io}}$$

Factorization of Energy into Activity and Average Intensity

We first note that the energy index is the product of the activity and average intensity indexes:

$$\frac{E}{E_o} = \frac{A}{A_o}\frac{\Omega}{\Omega_o}$$

Next, we note that for any two quantities "x" and "y" we have:

$$xy-1 = (x-1) + (y-1) + (x-1)(y-1)$$

This identity is useful when "x" and "y" are indexes because it states that if an index is the product of two other indexes, the *change* in the index is the sum of the changes of the two indexes plus an interaction term that is the product of the changes in the two indexes. (This identity will be used at several points in the following development when we need to factor the product of two indexes.)

This identity allows us to factor the change in the energy index into a total activity component, an average intensity component and an interaction term:

$$\frac{E}{E_o}-1 = (\frac{A}{A_o}-1) + (\frac{\Omega}{\Omega_o}-1) + (\frac{A}{A_o}-1)(\frac{\Omega}{\Omega_o}-1)$$

For brevity, we designate the interaction term as "ε."

The Structure and Intensity Indexes

The average intensity index is defined in terms of its subsector activity shares and intensities as follows:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_{io}\Omega_i}{\sum_i a_{io}\Omega_{io}}$$

Represented this way, we see that movements in the average sector intensity consist of movements in activity shares and in the intensities of the subsectors. To isolate these effects, we define two other indexes. Each index uses the same formula as above, but holds one of the quantities fixed at a base-period value.

We define the ("pure") structure index as:

$$\frac{S}{S_o} = \frac{\sum_i a_i \Omega_{io}}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' intensities remained fixed at base-period values.

Similarly, we define the ("pure") intensity index as:

$$\frac{I}{I_o} = \frac{\sum_i a_{io} \Omega_{io}}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' activity shares remained fixed at base-period values.

The Base-Weighted Form of the Indexes

Before introducing the factorization of the average intensity into its structure and "pure" intensity components, it is useful to note that the structure and intensity indexes have a simple representation as the base-period energy-weighted sum of simple indexes.

We note that the structure index can be represented as follows:

$$\frac{S}{S_o} = \frac{\sum_i a_i \Omega_{io} \frac{a_i}{a_{io}}}{\sum_i a_{io} \Omega_{io}}$$

We also note that:

$$\frac{a_{io} \Omega_{io}}{\sum_i a_{io} \Omega_{io}} = \frac{E_{io}/A_o}{E_o/A_o} = \frac{E_{io}}{E_o} = b_i$$

Where "b_i" is the base-period energy share of the "ith" subsector. (Note that we will not use the "o" subscript for "b_i"—this notation will always refer to the base-period energy share.) This yields the following representation of the structure index:

$$\frac{S}{S_o} = \sum_i b_i \frac{a_i}{a_{io}}$$

That is, the structure index is the base-period, energy-share weighted sum of the subsector activity share indexes.

In exactly the same way, we derive the following representation for the intensity index:

$$\frac{I}{I_o} = \sum_i b_i \frac{\Omega_i}{\Omega_{io}}$$

So the "pure" intensity index for the sector is simply the base-period, energy-share weighted sum of the subsector *average* of the intensity indexes. (Note the emphasis; the "pure" intensity index is *not* the weighted sum of subsector "pure" intensity indexes. We will denote the "pure" intensity index with the Roman letter "I" and average intensities with the Greek letter Ω.)

Finally, we note that since the base-period weights sum to unity, the above two formulas also hold in index-change form. In particular:

$$\frac{S}{S_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} - 1\right) \text{ and } \frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1\right)$$

Factorization of Intensity into Structure and "Pure" Intensity

We return to the average intensity index and demonstrate its relationship to the structure and "pure" intensity indexes. Using the same device as in the previous section:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_i \Omega_i}{\sum_i a_{io} \Omega_{io}} = \frac{\sum_i a_i \Omega_{io} \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}}{\sum_i a_{io} \Omega_{io}} = \sum_i b_i \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}$$

Since the base-period energy shares sum to unity, the above can be written as:

$$\frac{\Omega}{\Omega_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}} - 1 \right)$$

Observe that the quantity in parentheses is the change in the product of two indexes—so it can be factored (as with the total energy index) as follows:

$$\frac{\Omega}{\Omega_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} - 1 \right) + \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1 \right) + \sum_i b_i \frac{a_i}{a_{io}} - 1)\left(\frac{\Omega_i}{\Omega_{io}} - 1 \right)$$

This demonstrates the relationship sought: the first sum is the structure index and the second is the “pure” intensity index. The third term—which is a sum of “interaction terms,”—will be denoted by "δ." So *changes* in the average intensity index are related to the two other indexes as follows:

$$\frac{\Omega}{\Omega_o} - 1 = \left(\frac{S}{S_o} - 1 \right) + \left(\frac{I}{I_o} - 1 \right) + \delta$$

Note that this completes our factorization of the total energy index:

$$\frac{E}{E_o} - 1 = \left(\frac{A}{A_o} - 1 \right) + \left(\frac{\Omega}{\Omega_o} - 1 \right) + \varepsilon$$

$$= \left(\frac{A}{A_o} - 1 \right) + \left(\frac{S}{S_o} - 1 \right) + \left(\frac{I}{I_o} - 1 \right) + \delta + \varepsilon$$

where, as before, ε is the intensity-activity interaction term and δ is the structure-intensity interaction term.

In anticipation of needs in the next section, we introduce some notation here concerning the interaction term ε. First, recall that from the definition of ε and the factorization formula for average intensity, we have:

$$\varepsilon = \left(\frac{A}{A_o} - 1 \right)\left(\frac{\Omega}{\Omega_o} - 1 \right) = \left(\frac{A}{A_o} - 1 \right)\left[\left(\frac{S}{S_o} - 1 \right) + \left(\frac{I}{I_o} - 1 \right) + \delta \right]$$

so ε can be represented as the sum of three “interaction terms”:

$$\varepsilon_1 = (\frac{A}{A_o} - 1)(\frac{S}{S_o} - 1) = (\frac{A}{A_o} - 1)\sum_i b_i (\frac{a_i}{a_{io}} - 1)$$

$$\varepsilon_2 = (\frac{A}{A_o} - 1)(\frac{I}{I_o} - 1) = (\frac{A}{A_o} - 1)\sum_i b_i (\frac{\Omega_i}{\Omega_{io}} - 1)$$

$$\varepsilon_3 = (\frac{A}{A_o} - 1)\delta = (\frac{A}{A_o} - 1) = \sum_i b_i (\frac{a_i}{a_{io}} - 1)(\frac{\Omega_i}{\Omega_{io}} - 1)$$

These three terms will be used in the development of the next section.

Two-Way Factorization of Total Energy

The factorization of a sector's energy index into activity, structure and intensity indexes (with attendant interaction terms) provides measures that summarize different influences on the movements of the total energy index. However, the individual contributions of the subsectors to each of these indexes is also of interest. For example, if we observe movements in the intensity index, it is useful to know which subsectors are contributing to the movement and in which direction. This is true even if there are no movements in the aggregate index, since this may be due to offsetting contributions of the subsectors.

The subsector composition of the change in the aggregate indexes can also reveal useful patterns both between subsectors and between aggregate indexes. For example, it may reveal that one set of subsectors is moving the aggregate energy index via the structure and activity indexes, while a different set of subsectors is moving the energy index via the intensity index.

These considerations motivate the development of the "two-way" decomposition formulas described in this section.

We first note that:

$$\frac{E}{E_o} = \sum_i \frac{E}{E_o} \frac{E_i}{E_{io}} = \sum_i b_i \frac{E_i}{E_{io}}$$

or in index change form:

$$\frac{E}{E_o} - 1 = \sum_i b_i (\frac{E_i}{E_{io}} - 1)$$

Thus an individual subsector's (total) contribution to the change in the sector's total energy index is simply the change in its own energy index times its base-period energy share.

We note that the change in the subsector's energy index can be represented as follows:

$$\frac{E_i}{E_{io}}-1=\frac{A}{A_o}\frac{a_i}{a_{io}}\frac{\Omega_i}{\Omega_{io}}-1$$

Factoring the product twice yields:

$$\frac{E}{E_{io}}-1=(\frac{A}{A_o}-1)+\frac{a_i}{a_{io}}-1)+\frac{\Omega_i}{\Omega_{io}}-1)+\frac{a_i}{a_{io}}-1)+\frac{\Omega_i}{\Omega_{io}}-1)+$$

$$\frac{A}{A_o}-1(\frac{a_i}{a_{io}}-1)+\frac{A}{A_o}-1)(\frac{\Omega_i}{\Omega_{io}}-1)+(\frac{A}{A_i}-1)\frac{a_i}{a_{io}}-1)(\frac{\Omega_i}{\Omega_{io}}-1)$$

Multiplying this equation through by "b_i" and summing over "i" we see that each of the sums on the right-hand side add to, respectively, the change in the total sector activity index, the change in the structure index, the change in the "pure" intensity index, δ, ε_1, ε_2, and ε_3.

This completes the two-way factorization of the changes in the total energy index. The factorization yields values for the following table:

	Total Energy	**Activity**	**Structure**	**Intensity**	**Interaction Terms**
Sector total					
Contributions of:					
Subsector 1					
Subsector 2					
. . .					
Subsector n					

This schematic represents the analytical framework used for studying movements in the various aggregate indexes at a given level of the "pyramid." Interesting observations in any subsector row of the table were pursued by "drilling down" to the next level of the pyramid.

Adjustments for Weather

Since weather can exert a large influence on the intensity of energy use, the "pure" intensity index suffers the defect that it includes weather effects. This section extends the factorization to include weather adjustments. These adjustments are applicable in the residential and commercial sectors for activities related to space heating and space cooling.

The weather adjustment takes the form:

$$\Omega = w\Omega'$$

where "w" is the weather adjustment and Ω is weather-adjusted intensity. For space-heating and space-cooling activities, an estimate of "w" is available directly in the form of a degree-day elasticity. However, for aggregate sectors that span subsectors with different weather adjustments or have only some subsectors subject to adjustment, the sector's total weather adjustment must be computed implicitly as:

$$w = \frac{\sum_i a_i \Omega_i}{\sum_i a_i \Omega'_i}$$

Using this notation, we incorporate the weather adjustment into our "pure" intensity index:

$$\frac{I}{I_o} -1 = \sum_i b_i (\frac{\Omega_i}{\Omega_{io}} -1 = \sum_i b_i (\frac{w_i \Omega'_i}{w_{io} \Omega'_{io}} -1)$$

Factoring the term in parentheses yields:

$$\frac{I}{I_o} -1 = \sum_i b_i (\frac{w_i}{w_{io}} -1) + \sum_i b_i (\frac{\Omega'_i}{\Omega'_{io}} -1) + \sum b_i \frac{w_i}{w_{io}} -1)(\frac{\Omega'_i}{\Omega'_{io}} -1)$$

This expresses the changes in the "pure" intensity index as the sum of the changes in a "pure" weather index, a "pure" weather-adjusted intensity index and a new interaction term. We will use the notation "W" for the "pure" weather index," I'" for the pure weather-adjusted intensity index and λ for the weather-intensity interaction term. Our factorization of changes in the total energy index (for sectors subject to weather adjustment) is now:

$$\frac{E}{E_o} -1 = (\frac{A}{A_o} -1) + (\frac{S}{S_o} -1 + (\frac{W}{W_o} -1 + (\frac{I'}{I'_o} -1) = \lambda + \delta + \varepsilon$$

The two new indexes can be interpreted in the same way as the other "pure" indexes. That is, the weather index measures what the energy index would have been had all factors but weather adjustment remained at base-period values, and the weather-adjusted index measures what it would have been had all factors but weather-adjusted intensities remained at base-period values.

Decomposition Applied to the Total Economy

The four sectors comprising energy use for the total economy lack a sensible common activity measure. So the decomposition of the total energy index into a total activity index, total structure index, etc., is problematic. However, recall that the changes in the energy index can be represented as:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{E}{E_{io}}-1\right)$$

(where "b_i,"as before, denotes the sectors base-period energy share) and that for each of the four sectors, we have decomposed the changes in their energy indexes as:

$$\frac{E_i}{E_{io}}-1\left(\frac{A_i}{A_{io}}-1\right)+\left(\frac{S_i}{S_{io}}-1\right)+\left(\frac{W_i}{W_{io}}-1\right)+\left(\frac{I'}{I'_o}-1\right)+\lambda_i+\delta_i+\varepsilon_i$$

so the changes in the total economy energy index can be written:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{A_i}{A_{io}}-1\right)+\sum_i b_i\left(\frac{S_i}{S_{io}}-1+\sum_i b_i\left(\frac{W_i}{W_{io}}-1\right)+\sum_i b_i\left(\frac{I'}{I'_o}-1\right)+\right.$$

$$\sum_i b_i\lambda_i+\sum_i b_i\delta_i+\sum_i b_i\varepsilon_i$$

We use this formula to attribute changes in the total economy energy index to "generic" activity, structure, weather, weather-adjusted intensity and interaction effects.

Notes on Interaction Terms

Recall that early in this development the following identity was introduced:

$$xy-1=(x-1)+(y-1)+(x-1)(y-1)$$

As stated, this identity is useful when studying an index that is the product of two other indexes, since it "factors" the changes in the product into the changes of the two indexes plus an interaction term. It is this identity on which the quality of our "factorization" rests. When the changes in "x" and "y" are "modest," this identity lets us ignore the interaction term, and we can focus on the behaviour of the two component indexes. As an example, the two component indexes can change by 10 percent and the interaction term will be only 1 percent. So in this case, we are not far wrong in ignoring the interaction term and saying that the product of the two indexes has changed by 20 percent of which 10 percent comes from "x" and another 10 percent from "y."

The direction of the error in the approximation depends on the direction of change in the component indexes. If the component indexes either both increase or both decrease, the interaction term is always positive, so the sum of the changes in the component indexes is an underestimate of the total change. If the component indexes differ in the direction of their changes, then the interaction term is always negative, so the sum of the changes overshoots the total change.

We can comfortably ignore the interaction term "ε," which is the product of the changes in the total activity index and the average intensity index—both of which we have reason to expect will change only modestly. However, we can not be sanguine about the δ and λ interaction terms since they are the *sum* of interaction terms across all subsectors. Even if there are reasons to believe that subsector interaction contributions are small, we must not neglect the fact that we are "adding them up." The interaction term "δ" deserves special consideration because one of the component indexes is the activity share index. Thus, we must be cautious in looking at components of δ when we expect that a subsector may have gained considerable activity share. A subsector that changes its activity share from 5 to 10 percent (or 1 to 2 percent) has an activity share index change of 100 percent, which stretches the notion of "modest." This condition is moderated somewhat by the fact that the contribution of the subsector to "δ" is weighted by its base-period energy share. That is, its contribution to the total interaction term will only be large if it has a large base-period energy share.

Decomposition Applied to End-Use Sectors

Total secondary energy consumed in the economy is the sum of the secondary energy consumed by each of the end-use sectors, as defined by NRCan (see Appendix C):

1) industrial
2) transportation
3) residential
4) commercial (including public administration)
5) agriculture

The factorization methodology provides a basis for distinguishing between activity, structure and intensity factors, but the activity measure appropriate for any particular sector may not be applicable to another. The following activity measures are used for each sector:

Industrial – GDP originating from the sector
Transportation – passenger-kilometres and freight tonne-kilometres
Residential – number of households
Commercial (including public administration) – floor space

Industrial Sector

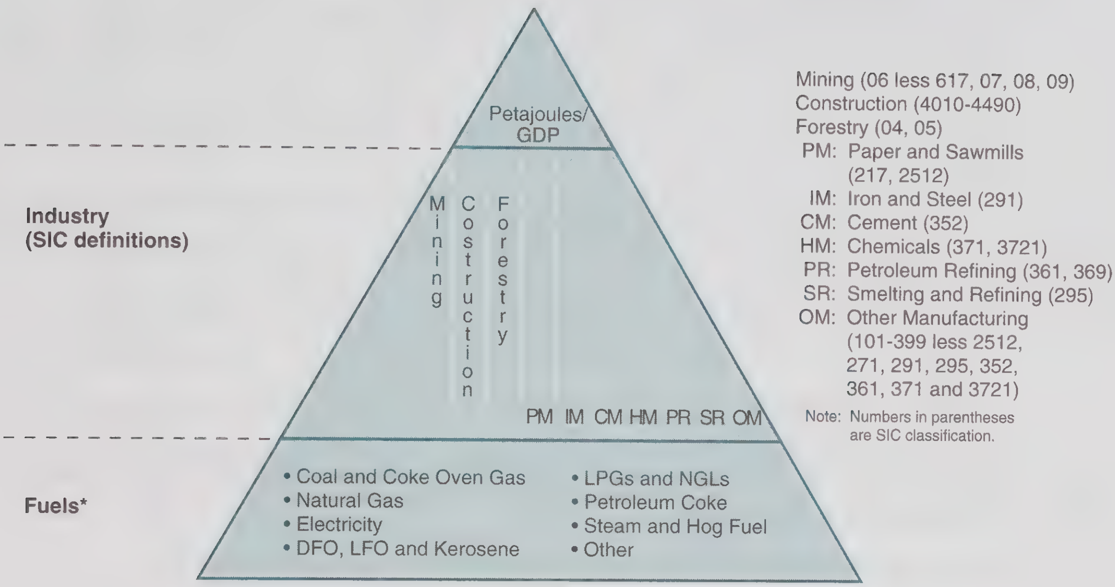
The industrial decomposition is based on energy consumption per unit of industrial output (GDP) for 11 sub-aggregates in the mining (2), construction (1), forestry (1) and manufacturing (7) subsectors.

Secondary end-use energy information is produced by NRCan for use in their industrial sector energy end-use models. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for hog fuel and pulping liquor consumption and producers' consumption of refined petroleum products.

Industrial output data for the 10 subsectors are aggregations of GDP by industry (at 1986 prices) data produced by Statistics Canada and published in *Gross Domestic Product by Industry* (15-001). Statistics Canada uses a Standard Industrial Classification system to identify industries; the combinations used in this analysis are identified on the industrial sector indicator pyramid. It should be noted that industry GDP disaggregated by fuel type is not available from Statistics Canada. Instead, estimates were constructed using shares of output energy demand.

As shown on the indicator pyramid (Figure B.1), the factorization of energy use for the industrial sector involves three levels. Level 1 (at the bottom) defines the sectoral influences at the most detailed level by fuel type. Level 2 captures the influence of shifting industrial composition. Aggregating over the products of these factors yields the third level, the change in aggregate industrial secondary end use attributable to each of the three components (activity, structure and intensity) in petajoules per unit of output.

Figure B.1
Industrial Sector Indicator Pyramid



DFO: diesel fuel oil

LFO: light fuel oil

LPGs: liquefied petroleum gases

NGLs: natural gas liquids

Transportation Sector

The structure for analysing transportation is based on a division of transportation activity into two parts: passenger and freight.

Passenger Transportation

The passenger transportation decomposition is based on energy consumption per passenger-kilometre for seven modal subaggregates in the road (3), bus (2), rail (1) and air (1) subsectors.

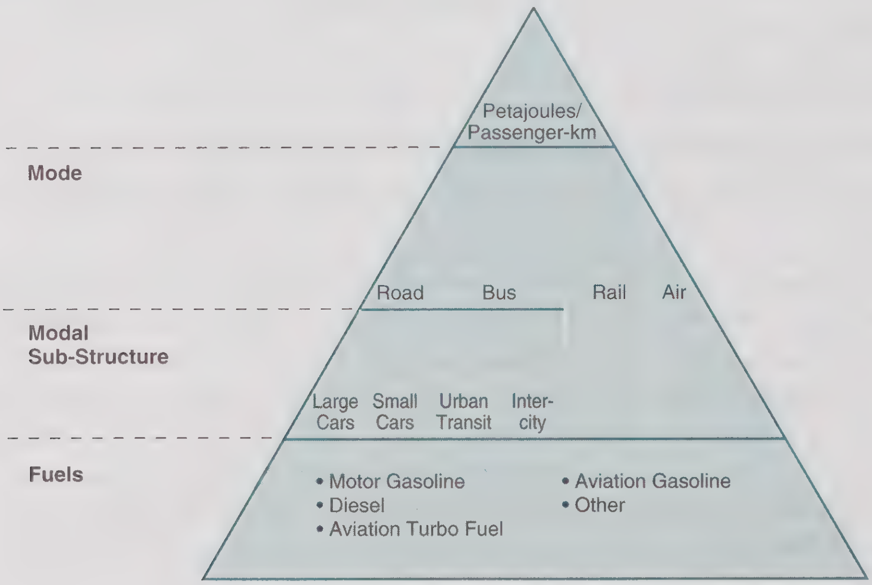
Secondary end-use energy information is produced by NRCan for use in its transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for motor gasoline, commercial and other institutional use of diesel fuel oil and aviation fuel, public administration use of aviation fuels and some historical revisions. Bus end-use energy demand was derived using data reported in Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215) and was netted off NRCan's reported energy use figures for medium/heavy and extra heavy trucks.

Passenger-kilometre data are drawn from a number of sources:

- Road data are based on the change in the average population per vehicle benchmarked in 1990 to the average number of passengers per car reported in the *Royal Commission on Passenger Transportation*, Volume 2, multiplied by the distance cars travel. The same average number of passengers per car benchmark is used for both large and small cars. Trucks are defined as light trucks, excluding those used for commercial purposes.
- Bus data are defined as the product of the total distance buses travelled and the average bus occupancy levels. Average bus occupancies are benchmarked in 1990 to the bus seat capacity and occupancy ratios of the *Royal Commission on Passenger Transportation*, Volume 2. Variations in bus occupancy levels are approximated based on the index of the ratio of total passengers to total distance travelled and an index of average trip distance. Total passenger and distance travelled data series are drawn from Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215), while the average trip distance data originates from the Commission de Transport de la Communauté de Montréal.
- Rail data are reported in Statistics Canada's *Rail in Canada* (52-216).
- Air data are drawn from NRCan's database, which is based on Statistics Canada's airline traffic statistics.

As shown on the indicator pyramid (Figure B.2), the factorization of energy use for the passenger transport sector involves four levels. In this instance, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.2
Passenger Transportation Indicator Pyramid



Freight Transportation

The freight transport decomposition is based on energy consumption per freight tonne-kilometre for five modal subaggregates in the truck (3), rail (1) and marine (1) subsectors.

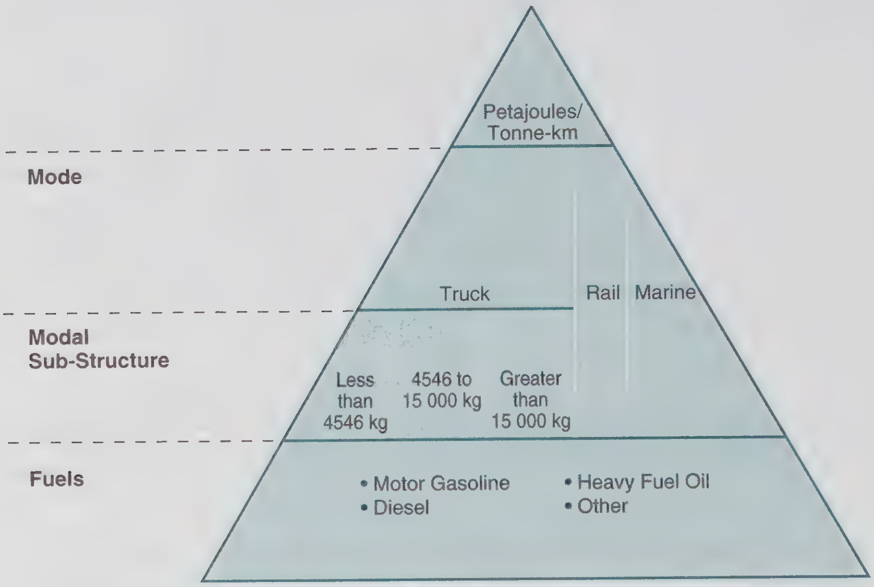
Secondary end-use energy information is produced by NRCan for use in their transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and some historical revisions. End-use energy demand by medium/heavy and extra heavy trucks was scaled down by the amounts reported for bus passenger transport.

Freight tonne-kilometre data are drawn from a number of sources:

- Truck data were drawn from Statistics Canada's *Trucking in Canada* (53-222). Light trucks are defined as excluding those used for personal use. Tonne-kilometres were attributed by fuel type based on input fuel consumption.
- Rail data were drawn from Statistics Canada's *Rail in Canada* (52-216).
- Marine data were drawn from Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

As shown on the indicator pyramid (Figure B.3), the factorization of energy use for the freight transport sector involves four levels. Once again, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.3
Freight Transportation Indicator Pyramid



Residential Sector

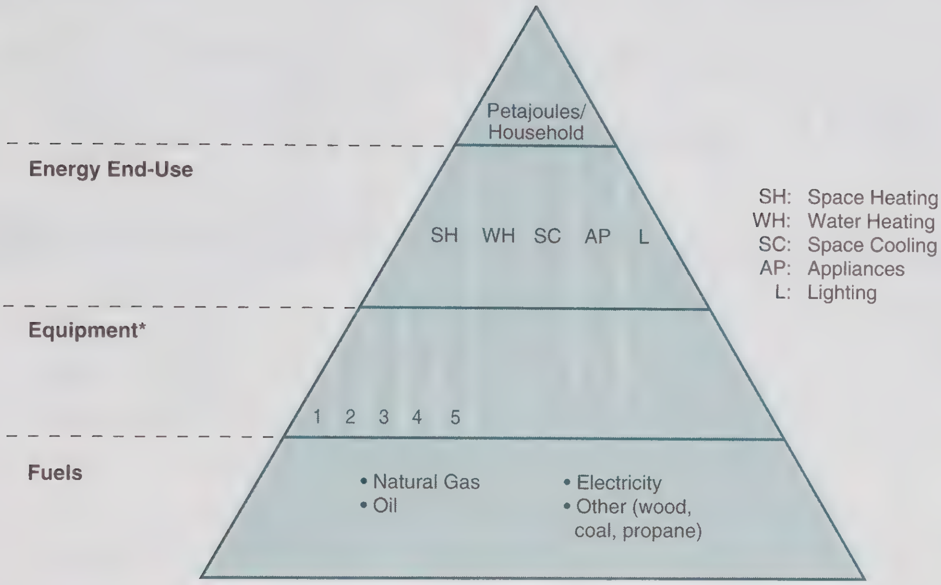
The residential decomposition is based on energy consumption per household.

Secondary end-use energy information is produced by NRCan for use in their residential sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for wood use; apartment fuel-use re-allocated from the commercial sector in Quebec, Ontario, Alberta and British Columbia; and some historical revisions. Electricity for street lighting, as published by Statistics Canada in *Electric Power Statistics* (57-202), was netted out of the factorization.

Household data are also produced by NRCan and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division and Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.4), the factorization of energy use for the residential sector involves four levels. For this sector, Levels 2 and 3 measure the impact of shifting appliance choice.

Figure B.4
Residential Sector Indicator Pyramid



* Equipment examples include:
Space heating - normal, mid- and high-efficiency furnace, electric baseboard heater, heat pumps, etc.
Space cooling - room air conditioner and central air conditioner
Appliances - refrigerator, freezer, clothes washer, electric and gas dryer, electric and gas ranges, dishwasher

Commercial Sector

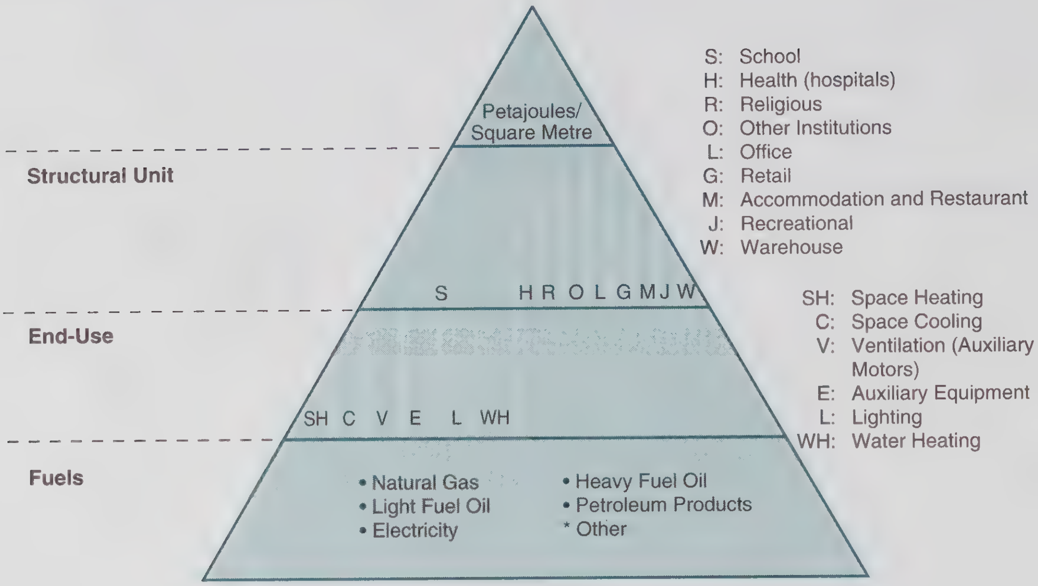
The commercial decomposition is based on energy consumption per square metre of floor space for nine building types.

Secondary end-use energy information is produced by NRCan for use in their commercial sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for apartment fuel use re-allocated to the residential sector in Quebec, Ontario, Alberta and British Columbia; diesel fuel oil use re-allocated to the transportation sector; and some historical revisions.

Floor space data are produced by Informetrica Limited for NRCan and are based on investment and capital stock data produced by Statistics Canada, Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.5), the factorization of energy use for the commercial sector involves four levels. For this sector, Level 2 captures appliance mix effects, while Level 3 captures the influence of building types.

Figure B.5
Commercial Sector Indicator Pyramid



Reconciliation of Data on Energy Use Found in this Report with Statistics Canada's *Quarterly Report on Energy Supply-Demand* Data, 1995

1 Introduction

The bulk of the energy-use data presented in this report is taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD). However, for the purpose of the analysis undertaken in this study, some sectoral re-allocations of the original Statistics Canada data were required. These adjustments are illustrated for the year 1995 in Table C.1 on page 106.

While our preference would have been to use QRESD data as is, some of the sectoral allocations in the QRESD were judged not to be adequate for energy end-use analysis. For example, Statistics Canada's definition of the commercial sector includes the use of aviation fuel by the public sector. NRCan's end-use analytical framework for the commercial sector estimates building energy use. Using unmodified QRESD sector definitions would have led to the inclusion of public-used aviation fuels in the commercial sector and their allocation to one of the building types defined in the NRCan's commercial end-use database. We did not find this approach acceptable for the type of analysis done in this report.

The following describes the modifications that were done to QRESD sector definitions in each end-use sector for the purpose of this report.

2 Residential Sector

Two modifications were made to the QRESD definition of the residential sector: the addition of fuel wood use and the re-allocation of apartment energy use from the commercial sector.

The inclusion of fuel wood use is a net addition to residential energy demand as reported in the QRESD. Residential fuel wood use is estimated using NRCan's Residential End-Use Model.

The re-allocation of apartment energy demand from the commercial to the residential sector is required because, in some provinces, utilities categorize apartments as commercial accounts. Since utilities report these data to Statistics Canada according to the account category, some apartment energy demand is misclassified in the commercial sector. This re-allocation is done with data provided by BC Gas, TransAlta Utilities, Ontario Hydro and Hydro-Québec.

3 Agricultural Sector

No modification.

4 Commercial Sector

Three modifications were made to the QRESD definition of the commercial sector: the re-allocation of apartment energy use to the residential sector, the re-allocation of commercial motive fuels to the transportation sector and the re-allocation of commercial butane demand to the non-energy sector.

The re-allocation of apartment energy demand from commercial to residential is the mirror adjustment to that described above for the residential sector.

The re-allocation of commercial motive fuels is done in order to include only stationary energy use in the commercial sector. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

The re-allocation of butane demand from commercial to non-energy demand is due to a misallocation of butane consumption in the QRESD. From 1993 until now, a significant and growing quantity of butane was reported as commercial and other institutional demand. The matter is currently under review by Statistics Canada and NRCan. At this point, all factors indicate that commercial butane demand is negligible and that the bulk of what is reported under commercial should be re-allocated to non-energy use. Until revised figures are finalized, we are re-allocating all reported commercial butane consumption to "non-energy use" for the purpose of this analysis.

5 Industrial Sector

Two types of modifications were done to the QRESD definition of the industrial sectors: a re-allocation of energy demand to another sector and a net addition of energy demand.

The re-allocation relates to producer consumption by the refining industry. Statistics Canada classifies the use of non-purchased petroleum products by the petroleum refining industry as producer consumption. In this report, this energy use has been re-allocated to the industrial sector (petroleum refining industry) as it is an end-use consumption. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

The net addition to energy use relates to solid wood waste and spent pulping liquor. Data on consumption of solid wood waste and spent pulping liquor are included in a supplementary table in the QRESD but not in the QRESD's energy supply-demand balance. For the purpose of this report, the energy demand of the industrial sector is modified to include solid wood waste and spent pulping liquor consumption. The location of these data in the QRESD are described in Table C.1.

6 Transportation Sector

Two modifications were made to the QRESD definition of the transportation sector: the re-allocation of commercial motive fuels from the commercial sector and the re-allocation of pipeline fuel use to producer consumption.

The re-allocation of commercial motive fuels from the commercial sector to the transportation sector is the mirror adjustment to that described above for the commercial sector.

The reallocation of pipeline fuel use to producer consumption is done in order to include only vehicle energy use in the transportation sector. Since pipeline fuel is used in the distribution of energy to end-use markets, we have re-allocated it to producer consumption and do not consider it end-use consumption. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

Table C.1
Reconciliation of Data on Energy Use Found in this Report with Statistics Canada *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Petajoules)

SECTOR	QRESD DATA	Fuel Wood	Apartment Energy Use	Commercial and Public Admin. Aviation Fuel	Commercial and Public Admin. Motor Gasoline	Commercial Diesel	Commercial Butane	Pipeline Fuels	Hog Fuel and Pulping Liquor	Producer Consumption by Refining Industry	ENERGY EFFICIENCY TRENDS DATA
Residential	1254	92	30								1376
Agriculture	207										207
Commercial	1161		(30)	(33)	(54)	(69)	(34)				941
Transportation	2076			33	54	69		(245)			1986
Industrial	2165								486	239	2890
Final Demand	6862	92	0	0	0	0	(34)	(245)	486	239	7400
Non-Energy	727						34				761
Producer Consumption	1000							245		(239)	1006
Net Supply	8589	92	0	0	0	0	0	0	486	0	9166
Conversion Losses *	1551										1551
Total Primary	10139	92	0	0	0	0	0	0	486	0	10717

Note: Subtract numbers in brackets when adding across rows to arrive at the total shown in the right hand column.

Notes on sources of energy use data for five end-use sectors:

RESIDENTIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 43) plus fuel wood use (estimated from NRCan's Residential End-Use Model) plus apartment energy use classified in commercial accounts by some utilities (estimated using utilities' data).

AGRICULTURE:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 42).

COMMERCIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 44 plus line 45) less apartment energy use classified in commercial accounts by some utilities (estimated using utilities data) less commercial and public administration motor gasoline (in 1995 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) less commercial diesel (in 1995 issue of QRESD Table 1D, diesel fuel oil column, line 45) less commercial and public administration aviation gasoline (in 1995 issue of QRESD Table 1D, aviation gasoline column, line 44 plus line 45) less commercial and public administration aviation turbo fuel (in 1995 issue of QRESD Table 1D, aviation turbo fuel column, line 44 plus line 45) less commercial butane (in 1995 issue of QRESD, Table 16, Canada butane column, line 45).

TRANSPORTATION:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 41 as corrected in CANSIM) less pipeline fuels (in 1995 issue of QRESD, Table 1B, natural gas plus electricity plus petroleum products columns, line 38) plus commercial and public administration motor gasoline (in 1995 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) plus commercial diesel (in 1995 issue of QRESD, Table 1D, diesel column, line 45) plus commercial and public administration aviation gasoline (in 1995 issue of QRESD, Table 1D, aviation gasoline column, line 44 plus line 45) plus commercial and public administration aviation turbo fuel (in 1995 issue of QRESD, Table 1D, aviation turbo fuel column, line 44 plus line 45).

INDUSTRIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 30) plus hog fuel and pulping liquor (in 1995 issue of QRESD, Table 19) plus producer consumption by refinery industry of still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG (in 1995 issue of QRESD, Table 1D, still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG columns, line 15).

* Electricity conversion rates: Hydro-electricity converted at rate of 3.6 megajoules per kilowatt-hour; nuclear electricity converted at rate of 11.564 megajoules per kilowatt-hour.

Reconciliation of 1995 Data on Carbon Dioxide Emissions Found in this Report with Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995*

1 Introduction

The carbon dioxide emissions data presented in this report are estimated using emissions factors developed by Environment Canada. In this respect, the emissions estimates provided herein mirror the estimates presented in *Trends in Canada's Greenhouse Gas Emissions 1990 to 1995*, since both NRCan and Environment Canada use the energy demand data from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD) as a base. However, the two organizations use different sectoral mappings.

Environment Canada, on behalf of the National Air Issues Committee, prepares Canada's official emissions inventory according to the specifications of the Inter Governmental Panel on Climate Change. NRCan has developed a mapping that is most suited to energy end-use analysis. The objective of this appendix is to help readers understand the similarities and differences between Environment Canada and NRCan sectoral emissions estimates for the five end-use sectors covered in this report. The comparison is illustrated for the year 1995 in Table D.1 on page 109. The reader is referred to footnotes at the beginning of chapters 3 to 6 for a better understanding of the magnitude of difference for each end-use sector in the years 1990 and 1995, the base and end years used in the report.

2 Residential Sector

For the residential sector, the only difference in emissions estimates between the National Inventory and NRCan relates to the latter's re-allocation of energy use from the commercial to the residential sector to correct for the misallocation of some apartment energy use data in the QRESD. This adjustment is described in Appendix C.

3 Agricultural Sector

For the agricultural sector, Environment Canada reclassifies all farm diesel and motor gasoline in the transport sector, while NRCan leaves this consumption in the agricultural sector as is done in the QRESD.

4 Commercial Sector

There are three differences between the NRCan and Environment Canada definitions of the commercial sector.

First, there are two re-allocations of energy use done by NRCan. One is a re-allocation of apartment energy use that mirrors the adjustment described above for the residential sector. The other is a re-allocation of commercial sector butane consumption to the non-energy sector to correct for a misallocation of butane in the QRESD. This adjustment is described in Appendix C.

Second, there is a re-allocation of public administration diesel consumption by Environment Canada from the commercial sector to the transportation sector.

5 Industrial Sector

For the industrial sector there are two differences between the sectoral definitions of Environment Canada and NRCan. First, there is a re-allocation by Environment Canada of industrial diesel fuel use from the industrial sector to the transportation sector.

Second, there is NRCan's re-allocation of producer consumption of petroleum products by the petroleum refining industry from the producer consumption sector to petroleum refining within the industrial sector.

6 Transportation Sector

All of the differences to the boundary of the transportation sector between NRCan and Environment Canada are related to re-allocation or exclusion of QRESD data by Environment Canada from its inventory.

First, there is the re-allocation to the transport sector of public administration diesel consumption, industrial diesel, and farm diesel and motor gasoline. Second, there is the exclusion from the National inventory total of emissions resulting from the use of energy in the foreign marine and foreign aviation subsectors.

Table D.1
Reconciliation of 1995 Data on Carbon Dioxide Emissions Found in this Report with Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995* (megatonnes)

SECTOR	Energy Efficiency Trends Data	Apartment Energy Use	Public Admin. Diesel	Commercial Butane	Industrial Diesel	Farm Diesel	Farm Motor Gasoline	Foreign Aviation	Foreign Marine	Producer Consumption by Refining Industry	Environment Canada Data
Residential	43.4	(1.4)									42.0
Agriculture	11.6					(6.3)	(2.7)				2.6
Commercial	28.1	1.4	(1.7)	2.1							29.9
Transportation	136.7		1.7		7.7	6.3	2.7	(2.6) **	(2.0) **		150.5
Industrial	98.9				(7.7)					(14.1)	77.1
Final Demand	318.7	0.0	0.0	2.1	0.0	0.0	0.0	(2.6) **	(2.0) **	(14.1)	302.0
Conversion Losses	102.8										102.8
Producer Consumption	41.5									14.1	55.6
Industrial processes	38.1			(2.1)							36.0
Non-Energy Related*	3.2										3.2
Total Emissions	504 **	0	0	0	0	0	0	(2.6) **	(2.0) **	0	500

Note: Subtract numbers in brackets when adding across rows to arrive at the total shown in the right hand column.

* Includes carbon fluxes in agricultural soils and incineration of municipal waste.

** As required by International Reporting Guidelines, Canada's official National Inventory excludes emissions associated with Foreign Aviation and Foreign Marine. Excluding these emissions from Energy Efficiency Trends Data would result in total emissions equivalent to that reported in Canada's official National Inventory (i.e., 500 megatonnes).

Glossary of Terms

The Glossary is divided into five sections: General, Residential Sector, Commercial Sector, Industrial Sector, and Transportation Sector. The General section includes general terminology as well as terminology common to more than one sector.

General

Activity: Term used to characterize major drivers of energy use in a sector (e.g., number of households in the residential sector).

Building Envelope: The materials and surfaces in the building shell, including walls, ceilings, roof, basement walls, windows and doors.

Canada's National Action Program on Climate Change (NAPCC): Sets strategic directions in pursuit of Canada's commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000 and provides guidance for actions beyond the year 2000. The NAPCC persues sectoral and broad-based opportunities through the development of appropriate actions and measures by private and public jurisdictions, reviews progress, and makes adjustments as required.

Carbon Dioxide: A compound of carbon and oxygen formed whenever carbon is burned. Chemical formula: CO_2. Carbon dioxide is a colourless gas that absorbs infrared radiation mostly at wavelengths between 12 and 18 microns; it behaves as a one-way filter allowing incoming, visible light to pass through in one direction while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus, it acts as a greenhouse and has the potential to increase the surface temperature of the earth. Energy use accounts for 98 percent of CO_2 emissions.

Climate Change: A change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods.

Compressor: A compressor is used in refrigeration and cooling systems to compress vaporized refrigerant.

Cooling Degree-Days: A measure of how hot a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The cooling degree-days for a single day is the difference between that day's average temperature and 18°C, if the daily average exceeds the base temperature,

and it is zero, if the daily average is less than or equal to the base temperature. The cooling degree-days for a longer period of time is the sum of the daily cooling degree-days for the days in the period.

End Use: Any specific activity that requires energy, e.g., refrigeration, space heating, water heating, manufacturing processes, feedstocks.

Energy Efficiency Indicators: Indicators of how efficiently energy is used.

Energy Intensity: The amount of energy use per unit of activity (examples of activity measures in this report are households, floor space, passenger-kilometres, tonne-kilometres, or constant dollar value of gross domestic product by industry).

Energy Source: Any substance that supplies heat or power, e.g., petroleum, natural gas, coal, renewable energy, and electricity, including the use of a fuel as a non-energy feedstock.

Factorization Method: A method used to decompose changes in the total energy used in a sector over a certain period of time, into changes in the overall demand for that sector's output, changes in the structural composition of the sector, and changes in the energy intensity of the individual subsectors contributing to the sector's output. The factorization method used in this report is the Laspeyres index.

Fossil Fuel: Any naturally occurring carbon-based fuel, such as petroleum, coal, and natural gas.

Framework Convention on Climate Change (FCCC): United Nations convention to address climate change (see Climate Change) signed by more than 150 countries at the United Nations Conference on Environment and Development in Rio de Janeiro, June 1992. Canada became the eighth country to ratify the Convention, which entered into force on March 21, 1994, thereby committing to working towards stabilizing greenhouse gas emissions at 1990 levels by the year 2000.

Gigajoule (GJ): One gigajoule equals 1×10^9 joules. A joule is the international unit of energy—the energy produced by a power of one watt flowing for one second. There are 3.6 million joules in one kilowatt-hour (see Kilowatt-hour).

Global Warming: see Greenhouse Gas.

Greenhouse Gas: A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxides (N_2O). By far the most abundant greenhouse gas is CO_2, accounting for 70 percent of the greenhouse effect (see Carbon Dioxide).

Gross Domestic Product (GDP): The total value of goods and services produced by the nation's economy before deduction of depreciation charges and other allowances for capital consumption, labour and property located in Canada. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment and net foreign trade. GDP figures are reported in real 1986 dollars.

Heating Degree Days: A measure of how cold a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The heating degree-days for a single day is the difference between that day's average temperature and 18°C, if the daily average is below the base temperature, and it is zero, if the daily average exceeds or equals the base temperature. The heating degree-days for a longer period is the sum of daily heating degree-days for days in that period.

Hydroelectric Generation: Electricity produced by an electric generator driven by a hydraulic turbine.

Interaction Effect: In the factorization method, this is a weighted average of the change in activity, intensity and structure variables.

Kilowatt-hour (kWh): The commercial unit of electric energy equivalent to 1000 watt hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt light bulbs burning for an hour. One kilowatt-hour is equal to 3.6 million joules (see Watt).

Megajoule (MJ): One megajoule equals 1×10^6 joules (see Gigajoule).

Megawatt-hour (MWh): One megawatt-hour equals 1×10^6 watt-hours (see Kilowatt-hour).

Motive Power: Power provided by electric motors for driving fans, pumps, elevators or other types of equipment.

Penetration Rate: The rate at which a technology infiltrates the stock of buildings (e.g., number of refrigerators per household at a specified time).

Per Capita: Per person.

Petajoule (PJ): One petajoule equals 1×10^{15} joules (see Gigajoule).

Petroleum: A naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Primary Energy Use: Represents the total requirements for all uses of energy, including energy used by the final consumer (see Secondary Energy Use), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g., coal to electricity) and energy used by suppliers in providing energy to the market (e.g., pipeline fuel).

Production of Electricity: The amount of electric energy expressed in kilowatt-hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g., peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels and environmental constraints.

Real Disposable Income Per Household: Money, in constant dollars, available to individuals per household for spending and saving after taxes and social insurance premiums (unemployment insurance and Canada Pension Plan) have been deducted. Personal disposable income is the principal source of savings and spending in the economy.

Retrofit: Improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Secondary Energy Use: Energy used by final consumers for residential, agriculture, commercial, industrial and transportation purposes.

Sector: The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g., residential, agriculture, commercial, industrial, and transportation).

Space Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air conditioner or heat pump) or by circulating chilled water through a central-cooling or district-cooling system.

Space Heating: The use of mechanical equipment to heat all or part of a building. Includes both the principal space-heating and supplementary space-heating equipment.

Structural Change: As it affects energy efficiency, structural change is a change in the shares of activity accounted for by the energy-consuming subsectors within a sector. An example of structural change is change in product or industry mix in the industrial sector.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Vintage: The year of origin or age since the construction of a unit of capital stock (e.g., a building, a car).

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other non-cooking applications.

Watt (W): A measure of power, for example a 40-watt light bulb uses 40 watts of electricity (see Kilowatt-hour).

Weather-Adjusted Energy Intensity: A measurement of energy intensity that excludes the impact of weather.

Residential Sector

Annual Fuel Utilization Efficiency (AFUE): This is an energy rating (stated as a percentage, such as 90 percent) that indicates how efficiently a new furnace or boiler will heat a home. The higher the number, the more efficient the heating equipment.

Apartment: This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes, i.e., where the division between dwelling units is horizontal; suites in structurally converted houses; living quarters located above or in the rear of stores, restaurants, garages or other business premises; janitors' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions.

Appliances: Energy-consuming equipment used in the home for purposes other than condition of air or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, colour televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

Dwelling: A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside. A private dwelling is one which one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

Heated Living Area: The area within a dwelling that is space heated.

Household: A person or a group of persons occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings. The person or persons occupying a private dwelling form a private household.

Household Size: The number of persons per household.

Mobile Home: A moveable dwelling designed and constructed to be transported (by road) on its own chassis to a site and placed on a temporary foundation such as blocks, posts or a prepared pad. It should be capable of being moved to a new location.

Resistance Value: Resistance value, or R-value, represents a material's resistance to heat flow. The higher the R-value, the greater the insulating power.

Single-Attached Dwelling: Each half of a semi-detached (double) house and each section of a row or terrace is defined as a single-attached dwelling. A single dwelling attached to a non-residential structure also belongs to this category.

Single-Detached Dwelling: This type of dwelling is commonly called a single house, i.e., a house containing one dwelling unit and completely separated on all sides from any other building or structure.

Commercial Sector

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Ballasts: A ballast is a device used with a fluorescent-type lamp to provide the necessary starting and operating electric conditions.

Burner: The part of a gas or oil space-heating system that produces the flame and controls the ratio of air to fuel in the combustion mixture.

Floor Area (Space): The area enclosed by exterior walls of a building, including parking areas, basements or other floors below ground level. It is measured in square metres.

Occupancy Rate: The number of occupants per square metre of floor area.

T-8 System: Fluorescent lighting system using reduced diameter lamps (T-8 tubes have a diameter of 1 inch compared to 1.5 inches for standard tubes). Lamps of this type use less power to produce a similar amount of light as a standard lamp. However, they require special fixtures and dedicated ballasts.

Industrial Sector

Aluminum Smelters: Reduction cells or pots that contain cryolite bath needed by the aluminum industry to separate oxygen and aluminum from alumina.

Capacity-Utilization Rate: The ratio of industrial production to capacity (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule).

Chemical Pulping: A process that generates intact wood fibres using steam and various chemicals. This pulping process is used for high-quality and high-strength paper.

Clinker: An intermediate product in cement production. A grey granular material obtained from burning the raw material mixture (usually limestone, clay or shale, sand, bauxite and iron ore).

Coke: A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke Oven Gas: Complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Continuous Casting: A process that directly casts molten steel in a primary mill into smaller and thinner sections without the need for reheating steel ingots.

Dry Process Cement Production: Cement production process in which raw material grinding takes place in the absence of water, reducing the required heating temperature and time during clinker production.

Electric-arc Furnaces: Use of electrical arcs in a furnace to efficiently produce very high temperatures for applications such as metal melting and coating and industrial drying.

Ingot Casting: Casting method in which the material takes on the approximate shape of its final use. Reheating and soaking is then required before production of final product.

Integrated Mill: Facility that produces steel products from iron ore rather than from ferrous scrap.

Mechanical Pulping: A pulp and paper industry process where wood, in the form of chips or logs, is converted into fibres by abrasion. Because fibres are broken during this process, mechanical pulp and paper products are of lower quality.

Pulp Digesters: Pulp and paper technology used in chemical-pulping processes for the release of lignin, which bonds wood fibres.

Pulping Liquor: A substance primarily made up of lignin, other wood constituents, and chemicals that are by-products in the manufacture of chemical pulp. It can be burned in a boiler to produce steam or electricity through thermal generation.

Soderberg-type Smelters: Carbon anode production process used in the aluminum industry.

Standard Industrial Classification (SIC): Statistics Canada uses a classification system that categorizes establishments into groups with similar economic activities.

Wood Wastes: Fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

Transportation Sector

Alternative Fuels: Defined to include all fuels other than conventional fuels (i.e., motor gasoline and diesel) used in road transportation.

Drivetrain: The drivetrain of a vehicle consists of the engine, transmission, differential and the drive shaft.

Electronic Emissions Controls: These refer to the computerized control of engine operations to ensure that the catalytic converter is not overwhelmed by the mix of emissions it receives. Controls can affect the size of injector openings or the speed at which the fuel pump operates.

Engine Displacement: The volume of the space in the cylinder measured down to the top of a piston when it is furthest away from the the top of the cylinder times the number of cylinders in the engine.

Horsepower: The unit of power equal to 746 watts.

Large Cars: Defined as cars weighing more than 1179 kilograms (2600 lb).

Light Trucks: Defined as trucks up to 4536 kilograms (10 000lb) of gross vehicle weight.

Light Vehicles: Includes automobiles, motorcycles, and light trucks.

Passenger-kilometre: The transport of 1 passenger over a distance of 1 kilometre.

Passenger-seating Utilization to Capacity Ratio: This refers to the average number of people travelling in a vehicle compared to the average number of seating spaces in the average vehicle.

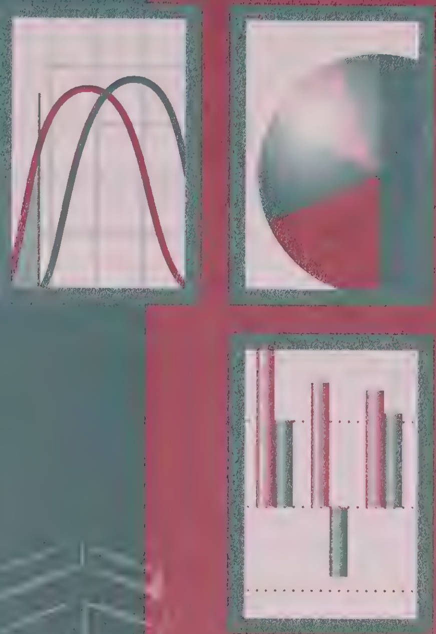
Small Cars: Defined as cars weighing up to 1179 kilograms (2600 lb).

Tonne-kilometre: The transport of 1 tonne over a distance of 1 kilometre.

Energy Efficiency Trends in Canada 1990 to 1996

A Review of Indicators of Energy Use, Energy Efficiency and Emissions

June 1998



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Office of Energy Efficiency
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Preface

This report, the third annual review of trends in end-use energy efficiency in Canada, delivers on Canada's commitment to track market trends in energy efficiency and their contribution to changes in energy use and greenhouse gas emissions. The analysis of these relationships, in turn, assists policy-makers in developing more effective responses to climate change and sustainable development issues.

Energy Efficiency Trends in Canada 1990 to 1996 differs from the first two reports in that it:

- addresses the period from 1990 to 1996;
- includes a separate overview of the agriculture sector;
- allocates electricity end-use related carbon dioxide emissions to the end-use sectors; and
- reviews the data situation by sector

As in the previous reports, the intent is to provide the reader with a detailed description of the framework, methodology and data sources used for the review. A database containing all energy indicators calculated for this report is available on the Internet by searching for *Energy Efficiency Trends in Canada* at **http://oee.nrcan.gc.ca/general/trends/index_e.htm**

The report was prepared by staff of the Demand Policy and Analysis Division of the Office of Energy Efficiency. The project leader was Michel Francoeur. Major contributors to the report were Maryse Courchesne, Alexandre Dumas, Bruno Gobeil, Tim McIntosh, Louise Métivier, Cristobal Miller, Alain Paquet, Nathalie Trudeau and Brian Warbanski. Nicholas Marty provided overall direction.

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The objective of *Energy Efficiency Trends in Canada 1990 to 1996* is to further our understanding of the contribution of energy efficiency to the evolution of secondary energy use and greenhouse gas emissions in Canada from 1990 to 1996.

In 1992, Canada signed and ratified the Framework Convention on Climate Change (FCCC), where over 150 countries agreed to work towards returning their own greenhouse gas emissions to 1990 levels by the year 2000. In December 1997, at the Third Conference of the Parties to the FCCC held in Kyoto, Japan, participating countries further agreed on a set of instruments and a timetable of emission reductions for the year 2010 relative to 1990. Canada committed to reduce greenhouse gas emissions 6 percent by 2010 relative to 1990 levels.

Along with its objective for sustainable development, Canada's objective for emissions reduction emphasizes the need for a good understanding of the main factors influencing the evolution of energy use and greenhouse gas emissions.

This report reviews energy use trends for five end-use sectors — residential, commercial, industrial, transportation and agriculture — over the 1990 to 1996 period and examines the influence of key factors on changes in energy use and carbon dioxide related emissions. The improved understanding of these relationships will assist policy-makers in assessing the progress made in developing more effective responses to Canada's greenhouse gas emissions reduction objectives.

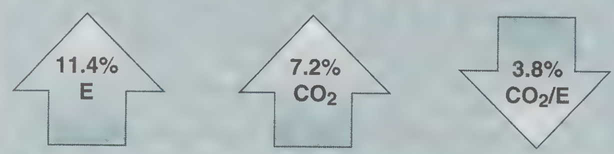
This year's report incorporates end-use electricity-related emissions at the sectoral level where electricity end-use is attributed an emissions factor reflecting the average mix of fuels used in its generation.

Secondary Energy Use and Emissions

At the secondary level, energy consumption and associated carbon dioxide emissions are concentrated in five sectors: residential, commercial, industrial, transportation and agriculture.

In 1996, secondary energy use accounted for about 70 percent of the total energy requirements in Canada. Emissions from secondary energy use and associated end-use electricity emissions are estimated to account for about 80 percent of all carbon dioxide emissions in Canada.

THE ENERGY/EMISSIONS BAROMETER – SECONDARY



From 1990 to 1996, secondary energy use (E) increased by 11.4 percent, from 6850 petajoules to 7632 petajoules, while resulting carbon dioxide emissions (CO_2) increased by 7.2 percent. Growth in emissions was less than growth in secondary energy use mainly due to a 3.8 percent decline in the carbon dioxide intensity (CO_2/E) of energy use. The decline in carbon dioxide intensity reflects a fuel shift at the end-use level, from oil products to natural gas, and a change in the mix of fuel used to produce electricity, from coal and heavy fuel oil to nuclear and natural gas.

The growth in secondary energy use was mostly influenced by a growth in activity levels in each end-use sector. Had only the level of activity changed in each sector from 1990 to 1996, while structure, weather and energy intensity remained at their 1990 levels, secondary

energy use would have increased by 714 petajoules, rather than the actual 782 petajoules.

Shifts in the structure of intra-sectoral activity (e.g., between industrial subsectors or between commercial building types) contributed to increase in the secondary energy use since 1990. From 1990 to 1996, the distribution of sector activity shifted toward more energy-intensive components of the Canadian economy. This shift contributed 207 petajoules to the increase in secondary energy use.

Weather also contributed to the increase in secondary energy use in the residential and commercial sectors. The winter of 1996 was colder than the winter of 1990, leading to increased space-heating requirements and an increase in secondary energy use of 130 petajoules.

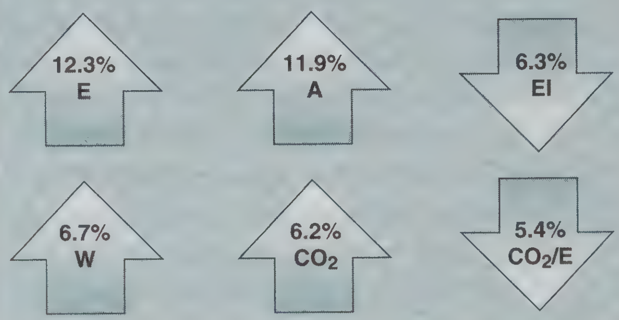
End-use energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1996. Had energy intensity remained at its 1990 level in each end-use sector and only activity levels, structure and weather changed, secondary energy use would have been 247 petajoules higher in 1996 than it actually was.

Residential Sector

In 1996, residential energy use accounted for 19.0 percent of secondary energy use and 17.1 percent of emissions from secondary energy use.

From 1990 to 1996, residential energy use (E) increased 12.3 percent to 1453 petajoules, while resulting carbon dioxide emissions (CO_2) increased by 6.2 percent. Growth in emissions was less than energy use mainly due to a 5.4 percent decline in the carbon dioxide intensity (CO_2/E) of energy use. The decline in carbon dioxide intensity reflects shifts in end-use fuel shares, which favoured natural gas to meet space- and water-heating requirements, and a change in the fuels used to generate end-use electricity.

THE ENERGY/EMISSIONS BAROMETER – RESIDENTIAL



The change in residential energy use was largely influenced by growth in economic activity (A) measured as the number of households, which increased 11.9 percent. Had all factors remained at 1990 levels and only activity changed, energy use would have increased 153 petajoules, rather than the actual 159 petajoules.

Weather (W) contributed to an increase in space-heating requirements of 87 petajoules as the winter of 1996 was colder than the winter of 1990. Although there was a slight impact of weather on space-cooling demand, its impact on total residential energy use was negligible as space cooling accounts for less than one percent of the energy requirements in this sector.

Aggregate energy intensity (E/A) increased 0.4 percent from 1990 to 1996, while energy intensity (EI), adjusted for weather and structure, declined by 6.3 percent. This decline in the energy intensity effect contributed to a decline of 82 petajoules over the period, partially offsetting

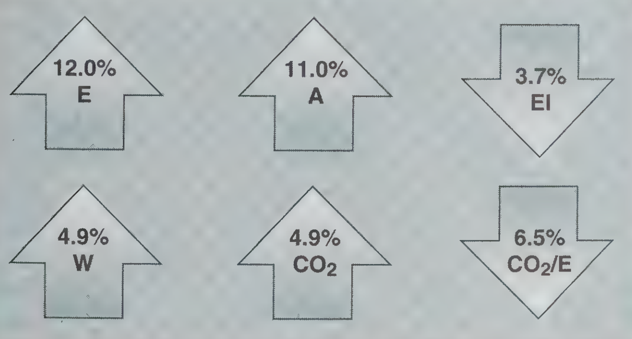
the increase in energy use associated with weather and the growth in activity. The decline in energy intensity was largely the result of improvements in the energy efficiency of space heating and appliances.

Commercial Sector

In 1996, commercial energy use accounted for 13.1 percent of secondary energy use and 12.4 percent of emissions from secondary energy use.

From 1990 to 1996, commercial energy use increased by 12.0 percent to 1000 petajoules, while resulting carbon dioxide emissions increased by just 4.9 percent. Growth in emissions was less than energy use mainly due to a 6.5 percent decline in the carbon dioxide intensity of energy use. As in the residential sector, the decline in carbon dioxide intensity reflects shifts in end-use fuel shares, which favoured natural gas to meet space- and water-heating requirements, and a change in the end-use electricity carbon dioxide intensity.

THE ENERGY/EMISSIONS BAROMETER – COMMERCIAL



The change in commercial energy use was largely influenced by growth in economic activity (measured as floor space growth), which increased 11.0 percent. Had all factors remained at 1990 levels and only activity changed, energy use would have increased 97 petajoules, rather than the actual 107 petajoules. Weather also contributed to an increase in energy use of 44 petajoules.

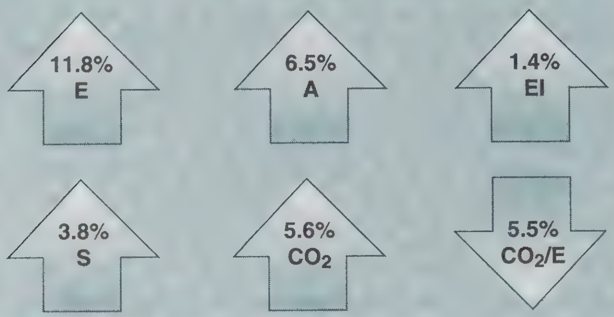
Aggregate energy intensity increased by 1.1 percent from 1990 to 1996, while energy intensity adjusted for weather and structure declined by 3.7 percent. This decline in the energy intensity effect contributed to a decline of 33 petajoules over the period, which partially offset the increase in energy use associated with weather and activity. The energy intensity effect was the result of increased energy efficiency of buildings and equipment and improved energy management practices of occupants.

Industrial Sector

In 1996, industrial energy use accounted for 38.3 percent of secondary energy use and 33.3 percent of emissions from secondary energy use.

From 1990 to 1996, industrial energy use increased by 11.8 percent to 2926 petajoules, while resulting carbon dioxide emissions increased by 5.6 percent. Growth in emissions was less than energy use mainly due to a 5.5 percent decline in the carbon dioxide intensity of energy use. The decline in carbon dioxide intensity reflects a fuel shift at the point of end-use from oil products, coal and coke oven gas to wood waste, pulping liquor and natural gas, as well as a change in the end-use electricity carbon dioxide intensity.

THE ENERGY/EMISSIONS BAROMETER – INDUSTRIAL



The change in industrial energy use was influenced by growth in economic activity (measured as real gross domestic product), which increased 6.5 percent over the period. Had all factors remained at 1990 levels and only activity changed, energy use would have increased 171 petajoules, rather than the actual 309 petajoules. A shift toward more energy-intensive industries, the structure effect (S), also contributed to an increase in energy use of 100 petajoules.

Aggregate energy intensity increased by 4.9 percent from 1990 to 1996, while energy intensity adjusted for structural shifts increased by 1.4 percent. Although the energy intensity effect for the industrial sector is positive, it does not imply that energy efficiency in the industrial sector has deteriorated. The increase in industrial sector energy intensity is a result of offsetting changes in specific industry groups, such as changes in product mix, operating practices, fuel mix and process mix within industry subsectors.

On an industry-by-industry basis, energy intensity declined in the petroleum refining (8.6%), smelting & refining (8.3%), iron & steel (1.2%) and other manufacturing (13.4%) industries. Conversely, energy intensity increased in the pulp & paper (8.6%), mining (20.2%), chemicals (13.9%) and cement (5.4%) industries.

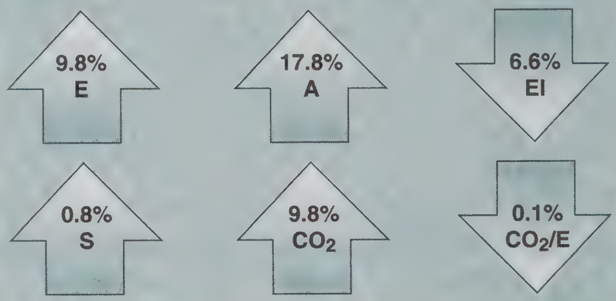
The increase in energy intensity occurred as a result of fuel switching and structural changes, such as a shift towards more energy-intensive products within an industry. Some of the structural factors that contributed to an increase in sectoral energy intensities include a shift towards more pulp production in the pulp & paper industry, more upstream activities in the mining industry and increased production of fertilizers in the chemical sector.

Transportation Sector

In 1996, transportation energy use accounted for 26.6 percent of secondary energy use and 33.6 percent of emissions from secondary energy use.

From 1990 to 1996, transportation energy use increased by 10.2 percent to 2029 petajoules. The increase in resulting carbon dioxide emissions was similar as changes in fuel shares had a negligible impact on the carbon dioxide intensity of energy use.

THE ENERGY/EMISSIONS BAROMETER – PASSENGER TRANSPORTATION

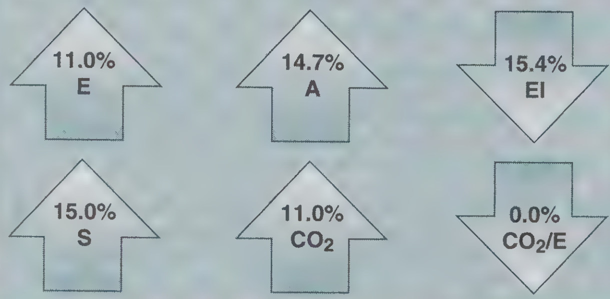


Passenger transportation energy use, which accounts for 65 percent of transportation energy use, increased by 9.8 percent from 1990 to 1996. This change is mainly the result of two offsetting factors: economic activity growth (measured as passenger-kilometres) and energy intensity (measured as energy per passenger-kilometre). Had all factors except activity remained at their 1990 levels, passenger transport energy use would have increased by 206 petajoules, rather than the actual 117 petajoules.

Aggregate energy intensity decreased by 5.9 percent from 1990 to 1996, while energy intensity adjusted for structural shifts declined by 6.6 percent. The 77 petajoule decline in energy intensity over the period partially offset the increase in energy use associated with growth in activity.

In the road passenger light vehicles segment (cars and light trucks), energy intensity declined due to the penetration of more efficient vehicles into the vehicle stock. The average economy of new car sales improved by nearly 8 percent, while the average economy of the stock of cars improved by over 8 percent from 1990 to 1996 (from 11.1 to 10.1 litres per 100 kilometres). These efficiency gains have occurred in the face of a trend toward heavier and more powerful vehicles in the 1990s.

THE ENERGY/EMISSIONS BAROMETER – FREIGHT TRANSPORTATION



Freight transportation energy use increased 11.0 percent between 1990 and 1996. Had all factors except activity (measured as tonne-kilometres) remained at their 1990 levels, freight transport energy use would have increased by 86 petajoules. The effect of structural shifts, away from marine towards trucks, contributed to an increase in energy use of 88 petajoules.

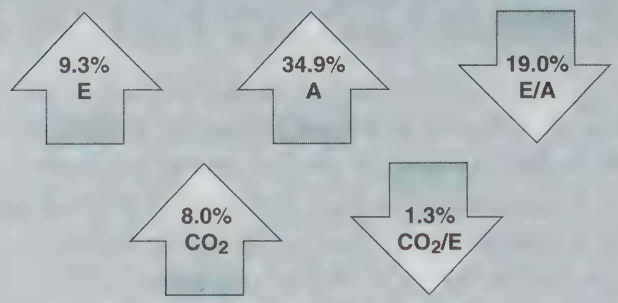
Aggregate energy intensity decreased by 3.2 percent from 1990 to 1996, while energy intensity adjusted for structural shifts declined by 15.4 percent. Had energy intensity not declined, freight transportation energy use would have been 91 petajoules higher in 1996.

Agriculture Sector

In 1996, agricultural energy use accounted for 2.9 percent of secondary energy use and 3.4 percent of emissions from secondary energy use.

From 1990 to 1996, agricultural energy use increased by 9.3 percent to 224 petajoules, while resulting carbon dioxide emissions increased by 8.0 percent. Growth in emissions was less than energy use mainly due to a 1.3 percent decline in the carbon dioxide intensity of energy use.

THE ENERGY/EMISSIONS BAROMETER – AGRICULTURE



The change in agricultural energy use was largely influenced by growth in economic activity (measured as real gross domestic product), which increased 34.9 percent. Had activity remained at the 1990 level, 1996 energy use would have been 43 petajoules lower. Alternatively, had aggregate energy intensity remained at the 1990 level, 1996 energy use would have been 77 petajoules higher.

Scope of the Report

HIGHLIGHTS

- This report examines market trends in energy efficiency, energy use and greenhouse gas emissions in the five major end-use sectors—residential, commercial, industrial, transportation and agriculture—over the period 1990 to 1996.
- A factorization method is used to separate the principal factors influencing the change in energy use and related emissions. Several factual and analytical indicators are reported to explain the trends in energy use and the factors underlying them.
- The quality and quantity of data upon which the analysis is based vary greatly across sectors. To improve these data, Natural Resources Canada (NRCan) has implemented the National Energy Use Database (NEUD) Initiative. The role of this initiative is to establish processes for the collection of data that will allow a better understanding of energy use in Canada.

In 1992, Canada signed and ratified the Framework Convention on Climate Change (FCCC). Under the FCCC, Canada and over 150 other countries agreed to work towards returning their own greenhouse gas emissions to 1990 levels by the year 2000. In the first Conference of the Parties (COP1) to the FCCC, held in Berlin in the spring of 1995, it was acknowledged that existing commitments to the year 2000 were not adequate to meet the ultimate goal of the FCCC to return greenhouse gas emissions to 1990 levels. Therefore, it was agreed to extend the commitments already in place and to negotiate a protocol or other legal instrument by the end of 1997. This agreement is known as the "Berlin Mandate."

The third Conference of the Parties (COP3) was held in December 1997 in Kyoto, Japan, where participating countries agreed to a timetable of emission reductions for the year 2010 relative to 1990. The European Union committed to reduce emissions by 8 percent, the United States by 7 percent and Canada and Japan committed to reduce emissions by 6 percent. For the 38 industrialized countries, the average reduction is 5.2 percent by 2010 relative to 1990 levels. Some developing countries will be allowed to increase their emissions. In all cases, commitments will need to be ratified by national governments before they become binding. This ratification process could take several years.

A key element of most countries' strategy to meet their emissions reduction objective is to increase energy efficiency in all sectors of the economy. In Canada, governments at all levels have programs to reduce the market barriers to energy efficiency and to accelerate the development and adoption of more energy-efficient technologies. The National Action Program on Climate Change (NAPCC) outlines the federal-provincial strategy for achieving the emissions reduction goal and provides guidance for action beyond the end of the century. Under the NAPCC, Canada has committed to develop indicators of progress towards meeting national objectives.[1] In February 1998, the federal government announced the establishment of a new central coordinating body to establish a revised national plan to meet the Kyoto commitments.

1 Government of Canada, *Canada's National Action Program On Climate Change*, Ottawa, Ontario, 1995, Chapter 5.

This report, the second update of *Energy Efficiency Trends in Canada* published in April 1996,[2] delivers on Canada's commitment to track market trends in energy efficiency and energy use and to understand its role in the growth of greenhouse gas emissions. An improved understanding of these relationships will, in turn, help policy-makers develop more effective responses to climate change.

As with both previous editions, this report covers the four major end-use sectors: residential, commercial, industrial and transportation. The three principal changes in this report compared to the 1997 report are as follows:

- This year, secondary energy use-related carbon dioxide emissions, which account for the majority of greenhouse gas emissions, include electricity generation emissions attributable to electricity end-use.
- The agricultural sector is analysed separately.
- The analysis focuses on the 1990 to 1996 period.

In addition, NRCan is working with the International Energy Agency to develop energy use indicators for other countries. This work will provide some comparative energy use indicators, and it will include a review of the relative strengths and weaknesses of such indicators. Development on these indicators will be reported on in future versions of this report.

The rest of this chapter describes the relationship between energy efficiency, secondary energy use and greenhouse gas emissions as well as the approach and the data used in this report to model these relationships. The rest of the report describes the results of the analysis for total secondary energy use and then the results by sector.

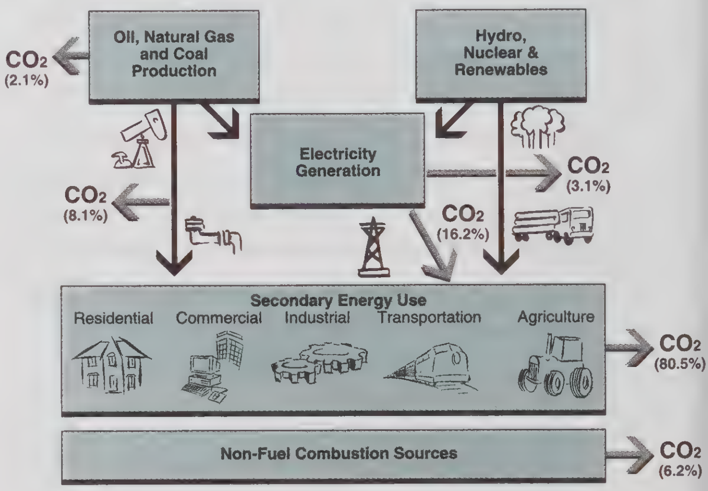
1.1 The Approach

The objective of this report is to:

- understand the influence of the factors affecting energy use and emissions; and
- explain the contribution of changes in energy efficiency (using energy intensity as a proxy) to the evolution of secondary energy use and carbon dioxide emissions.

The analysis in this report deals mainly with secondary energy use and the emissions resulting from this use. With the exception of electricity, it does not examine the emissions from the production of energy. Since all emissions associated with changes in electricity end-use arise during generation, in this report, end-use electricity has been attributed an emissions factor reflecting the average mix of fuels used to generate electricity. Secondary energy use emissions are inclusive of end-use electricity-related emissions and are defined as secondary energy use-related emissions.

Figure 1.1 The Relationship Between Secondary Energy Use and Carbon Dioxide Emissions



2 Natural Resources Canada, *Energy Efficiency Trends in Canada*, Ottawa, Ontario, April 1996. The first update was published in May 1997.

The relationship between secondary energy use and greenhouse gas emissions is illustrated in Figure 1.1. Emissions originate from secondary energy use and energy combustion, non-combustion uses of energy (industrial processes), electricity generation and oil and gas production. At the secondary level, most energy is used in five end-use sectors to meet specific end-uses such as space heating. The combustion of energy to meet these end-uses produces greenhouse gas emissions. The level of emissions varies according to the quantity and type of fuel used. Total carbon dioxide emissions in Canada are estimated in 1996 to amount to 515 megatonnes.[3] Of this amount, 416 megatonnes, or 80 percent, occurred as a result of energy use at the secondary or end-use level.[4] The latter amount decreases to 332 megatonnes, or 64 percent, when electricity-related end-use emissions are excluded.

1.1.1 Types of indicators

This report uses a variety of indicator types to explain the role of energy efficiency in the evolution of secondary energy use and emissions. An indicator is an index or any group of statistical values. For example, the level of employment is an economic indicator that gives an indication of the health of the economy. Energy use indicators measure the status of a specific segment of the economy. Indicators are often structured hierarchically from the most aggregate to the most disaggregate to provide a link between what we observe and the reasons for what we observe. The challenge is to improve these linkages.

The indicators used in this report have been categorized into two major types: factual and analytical.

Factual Indicators

Factual indicators are used to describe a situation. For example, how much energy is used and where it is used or the level of emissions in a given sector. Factual indicators can be further categorized into two types: snapshot and trend, according to the time dimension they portray. Snapshot indicators describe a situation at a point in time, while trend indicators describe the evolution of a situation over time.

Analytical Indicators

Analytical indicators are used to explain a situation. The two types of analytical indicators used extensively in this report are factorial and causal indicators. Factorial indicators are based upon an analysis of time series data where the source of change in one variable is attributed to the principal factors affecting that change. In this report, this approach has been applied to the change in energy use in each sector and, in so doing, has attributed to activity, structure, weather and energy intensity a contribution to the change in energy use. This factorization methodology is described below and in more detail in Appendix B.

Causal indicators are also used to explain a change in a particular variable. For example, energy price is a causal indicator that can explain a change in the level of energy use. Factorial indicators are also causal. The two causal type indicators are distinguished in this report to emphasize the fact that the "causes" highlighted in the factorization analysis are strictly and quantitatively related to the factor being explained, in this case the change in energy use. To explain cause and effect in other instances, a more qualitative approach of contrasting the trend in causal analytical indicators with the trend in the variable being explained is used. Table 1.1 illustrates the different types of indicators used in this report.

3 Estimated by Natural Resources Canada inclusive of foreign marine and airline energy-related emissions. 1996 Environment Canada inventory of emissions was not available at the time of production of this report.

4 From this point on in the report, reference to emissions implies energy-related greenhouse gas emissions from secondary energy use. This includes electricity-related end-use emissions.

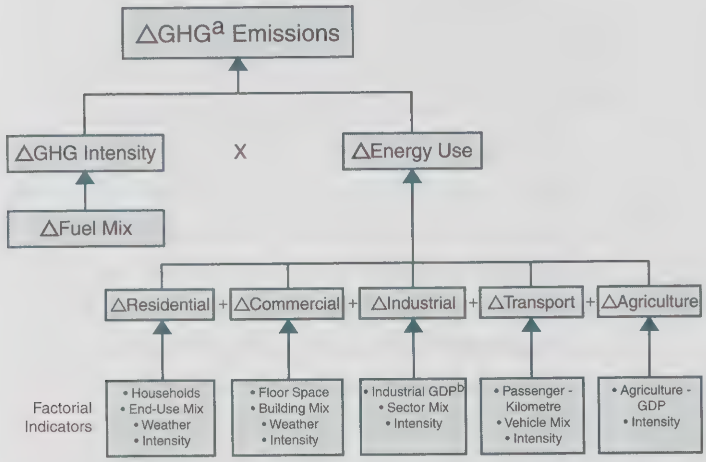
Table 1.1
Illustration of the Types of Indicators Used in this Report

Factual	Analytical
Snapshot	**Factorial**
households by type of dwelling, 1996	activity effect, 1990–1996
energy use by type of dwelling, 1996	structure effect, 1990–1996
energy use by end-use, 1996	energy intensity effect, 1990–1996
Trend	**Causal**
degree-day index, 1990 to 1996	housing stock by vintage, 1990 and 1996
energy intensity index, 1990 to 1996	gas furnace shipments by efficiency, 1990 and 1996
energy use index, 1990 to 1996	degree-day index, 1990 to 1996

1.1.2 Structure of the analysis

The analysis in this report is organized hierarchically within which the various types of indicators are used in the rest of the report.[5] This hierarchy deals, first, with the analysis of energy use and efficiency trends and, second, with the analysis of emissions trends. Figure 1.2 describes the analytic flow from the aggregate emissions at the top to the micro level factorial indicators at the bottom.

Figure 1.2 Analytic Framework for Monitoring Changes in Greenhouse Gas Emissions and Energy Use



a Greenhouse gas
b Gross domestic product

Analysis of trends in greenhouse gas emissions

Total greenhouse gas emissions can be expressed as the sum of emissions from non-combustion uses of energy, electricity generation, oil and gas production and secondary or end-use energy consumption. The focus of this report is on secondary energy use. The analysis of secondary energy use-related emissions presented in this report is the sum of emissions arising from the residential, commercial, industrial, transportation and agricultural sectors plus emissions related to electricity end-use.

The analysis of emissions from energy use to meet end-use requirements, which is presented in this report, is summarized in Appendix E. In each energy-consuming sector, energy-related emissions are the product of energy use and the carbon dioxide intensity of this energy use. The change in carbon dioxide emissions is approximated by the sum of growth in energy use and carbon intensity. The analysis of emissions presented in Chapters 3 to 7, which cover the five end-use sectors, respectively, elaborates on the principal factors underlying changes in both energy use and the carbon dioxide intensity of energy use,[6] thereby documenting the forces driving growth in energy-related carbon dioxide emissions.

5 Many of the methods used in this report were inspired by the work completed at the Lawrence Berkeley Laboratory (LBL) in Berkeley, California, and at l'Agence de l'environnement et de la maîtrise de l'énergie (ADEME) in Paris, France. The following two publications illustrate this work: Schipper, L.; Myers, S.; Howarth, R.; Steiner, R.: *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge University Press, Cambridge, Great Britain, 1992; and ADEME, *Cross Country Comparisons on Energy Efficiency Indicators: Phase 1*, Paris, France, November 1994.

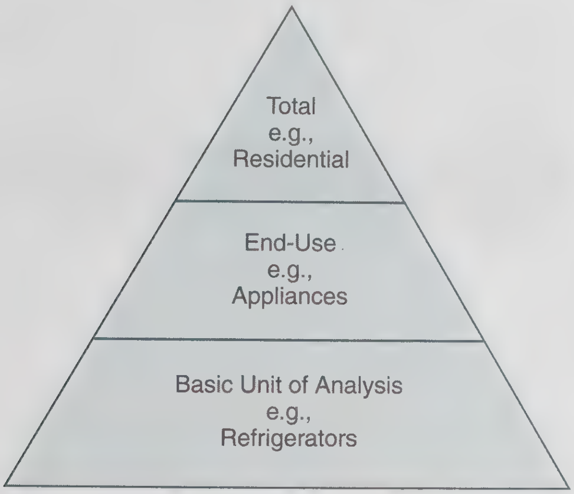
6 The carbon dioxide intensity of energy use is a weighted average of fuel-specific carbon dioxide intensities. The weights used in the calculation of this intensity for a given sector are the shares of energy demand accounted for by each fuel in that sector. In this report, analysis of changes in the carbon dioxide intensity of energy use in each sector will focus on a review of shifts in the fuel mix for that sector.

Analysis of trends in energy use and efficiency

The principal objective of this report is to isolate and then relate trends in energy intensity to trends in aggregate energy use and, ultimately, to trends in emissions. The relationship between such indicators is complex because the linkages are not transparent. The indicators pyramid is a useful tool to establish the relationship among the various indicators for a given sector.

Figure 1.3 illustrates the indicator pyramid for the residential sector. The pyramid presents energy use at increasing levels of detail from its most aggregate representation at the apex to an account of energy use by equipment type at the base. Indicator pyramids for other sectors are presented in Appendix B.

Figure 1.3 The Indicator Pyramid: A Residential Sector Illustration



While the pyramid serves to structure the indicators, it does little to *explain* the contribution of changes in one indicator to changes in another. In this report, the factorization methodology is used to attribute the change in energy use at any level of the pyramid to four factors: activity, mix of activity, weather, and energy intensity. For example, a factorization of total residential energy use would attribute the change in energy use to a growth in households (activity), to the change in the end-use mix (structure), to the change in weather and to the change in the energy intensity of each of the end-uses.

Increases in sector activity lead to increased energy use and emissions. In the residential sector, for example, if all other factors remained the same, an increase in the number of households would have the effect of increasing energy use.

A shift in the structure of activity towards more energy-intensive components of activity, all other things remaining constant, leads to increased energy use and emissions. For example, if the distribution of activity in the industrial sector shifts from forestry to the pulp & paper industry, an increase in industrial energy use will result as the former is much less energy-intensive than the latter. The definitions of activity and structure used in this report for each sector are described in Table 1.2. The factorization results will vary if different definitions of activity and structure are used.

Table 1.2
Definitions of Activity and Structure Used in this Report, by Sector

Sector	Activity	Structure
Residential	number of households	end-use mix: e.g., space heating, space cooling, appliances, lighting and water heating
Commercial	floor space	building mix: e.g., office, retail stores and hotel/restaurant
Industrial	gross domestic product	sector mix: e.g., pulp & paper, other manufacturing and iron & steel
Transportation	passenger- and freight-kilometres	mode mix: road, rail, air and marine
Agriculture	gross domestic product	n.a.

Fluctuations in weather lead to changes in space-heating and -cooling requirements. A colder winter or a warmer summer can both lead to increased energy use. The weather effect is most significant in the residential and commercial sectors where both heating and cooling requirements are important.

For the purpose of this report, the energy intensity effect is used as a proxy for energy efficiency. Technical energy efficiency can only be measured at the "micro" level (e.g., the energy efficiency of a refrigerator or a furnace). While the sectoral pyramids allow us to "drill" down to significant levels of detail, even the most disaggregate energy intensity effects presented in this report will reflect factors in addition to energy efficiency. In the industrial sector, for example, the most disaggregate energy intensity is an industry-specific intensity. This intensity effect reflects, in addition to energy efficiency, shifts in the mixes of product, process and/or fuel for that industry.

Nevertheless, by isolating the importance of activity, structure and weather, it is possible to estimate the impact of the energy intensity effect on changes in energy consumption. This energy intensity effect is a better measure of efficiency than aggregate energy intensity (i.e., energy divided by activity) because it separates out the influence of structure and weather as well as activity. The change in energy intensity effect can be interpreted as an "indicator" of the change in energy efficiency, the latter of which is only directly measurable at the greatest level of disaggregation.

1.2 The Data

Good quality data on energy use, emissions and activity levels in each end-use sector are crucial to the quality and accuracy of analysis.

The strength of this report rests upon explicit recognition of the importance of the method and the availability and quality of the data upon which the results are based. Therefore, this section provides an overview of the strengths and weaknesses of the major data used in this report. Detailed sources and definitions of the data presented in this report are documented in Appendices A, B and C.

Activity

In the residential and industrial sectors, activity measures are from Statistics Canada. In general, these measures are quite adequate and well aligned with the coverage of energy use. Activity measurement difficulties arise in the commercial and transportation sectors.

In the commercial sector, the measure of activity is floor space. The floor space data used in the analysis presented in this report include little actual data on floor area. The estimates of floor space result from an estimation procedure that uses data on investment flows and capital expenditures by structure and asset type and average construction cost data.

During this past year, efforts were made to integrate all existing data on commercial floor space into the floor space estimation procedure and analysis. This is an interim solution until a national survey on commercial building characteristics and energy use is completed. Details of NRCan's data collection strategy for the commercial sector are provided in Chapter 4.

In the transportation sector, passenger transport activity is defined as passenger-kilometres, while freight activity is defined using tonne-kilometres. Unfortunately, the data available to create either of these measures are partial.

Passenger-kilometre data for air and rail travel are available from Statistics Canada. Light vehicle and bus passenger-kilometres are estimated from data on vehicle and bus stocks, average distance travelled and occupancy ratios. For these variables, data are only available for selected years, and time series have been constructed by estimating missing years.

Tonne-kilometre data are available from Transport Canada for marine freight activity and from Statistics Canada for rail freight activity and part of trucking activity. The coverage of trucking activity has been expanded in this report compared to the 1997 report, but it remains partial. A research group has been commissioned to review the trucking market segment and recommend possible solutions to further improve the activity measure.

Energy use

Sectoral energy use data are from Statistics Canada's *Quarterly Report on Energy Supply–Demand* (QRESD), Canada's official energy balance. These data are available by fuel type for the major end-use sectors.

In the industrial sector, QRESD data are available for 10 branches of industry. For the residential, commercial and transportation sectors, specific energy use data below the aggregate sector amount are estimated by NRCan through an end-use modelling approach.

In the residential sector, energy demand estimates for each end-use are derived through a calibration process that takes into account aggregate energy use and detailed data on the characteristics of buildings and household equipment.

In the commercial sector, a modelling approach is also used to estimate end-use demand by building type. These end-use estimates are arrived at judgmentally through discussion with sector experts. Among the five sectors, energy use data problems are most limiting in the commercial sector.

In the transportation sector, the split in energy use between passenger and freight transport is estimated using a modelling approach that calibrates vehicle stock characteristics, distance travelled and vehicle fuel economy data to aggregate road transport sector energy use. Data improvements during this past year include an assessment of off-road residential and industrial motor gasoline consumption and bus and motorcycle energy use. Energy use for rail, air and marine are available from Statistics Canada's QRESD.

Greenhouse gas emissions

The greenhouse gas emissions data presented in the report are the result of multiplying the energy use data by emissions factors taken from Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. The differences between total sector-specific emissions presented in this report and those presented by Environment Canada are due to differences in sectoral definitions (i.e., re-allocations of QRESD energy data from one category to another by Environment Canada or NRCan or both). These differences are documented in Appendix D.

Canada's National Energy Use Database Initiative

The reliability of energy use analysis largely depends on the quality of the data available to undertake such analysis. Without a process to collect high-quality information on a regular basis, the analysis will not progress.

Recognizing the state of data collection in the area of energy use, NRCan has made data collection an integral part of its Energy Efficiency and Alternative Energy Program through the National Energy Use Database (NEUD) Initiative. Through this initiative, processes have been established for the regular collection of detailed data on energy use and the characteristics of energy-using equipment and buildings in all sectors of the Canadian economy.

The major energy end-use surveys that have been conducted include:

Industrial Consumption of Energy Survey
conducted annually and extended in 1994 to increase national coverage

National Private Vehicle Use Survey
conducted from October 1994 to September 1996

Survey of Household Energy Use
conducted in 1993 to cover the 1993 stock of households and repeated in February 1998 for the 1997 stock of households

Survey of Canadian New Household Equipment Purchases
conducted in 1994 and 1995 for purchases of new appliances

Appliance Shipment Data
completed in 1997 for manufacturers' shipments in years 1990 through 1996

Survey of Houses Built in Canada in 1994
conducted in 1995 for houses built in 1994

Home Energy Retrofit Survey
conducted in 1994 and repeated in 1995

Farm Energy Use Survey
conducted in 1997

NRCan is presently at the testing phase with respect to the *Commercial Buildings Energy Use Survey*. This phase will be completed by mid-1998.

In addition to designing and funding these surveys, NRCan has established, under the NEUD initiative, five Data and Analysis Centres, each of which specializes in the collection and analysis of energy use data for a specific sector.

More information on the survey activities of the NEUD and on the Data and Analysis Centres is available on request. E-mail: neud.bnce@nrcan.gc.ca

1.3 Overview of the Report

Chapter 2 reviews aggregate trends in secondary energy use and emissions from 1990 to 1996 and provides an overview of the contribution of sectoral trends to these aggregate trends.

Chapters 3 to 7 provide an in-depth analysis of the trends in energy use and emissions for each of the five end-use sectors. The analysis of energy use attributes to activity, structure, weather and energy intensity a contribution to the change in energy demand.

Appendix A presents the data and sources used to prepare the graphs in the report.

Appendix B presents the methodology and data sources that underlie the factorization of energy use.

Appendix C and D present a reconciliation of the sectoral definitions used in this report with those found in Statistics Canada's QRESD and Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995*.

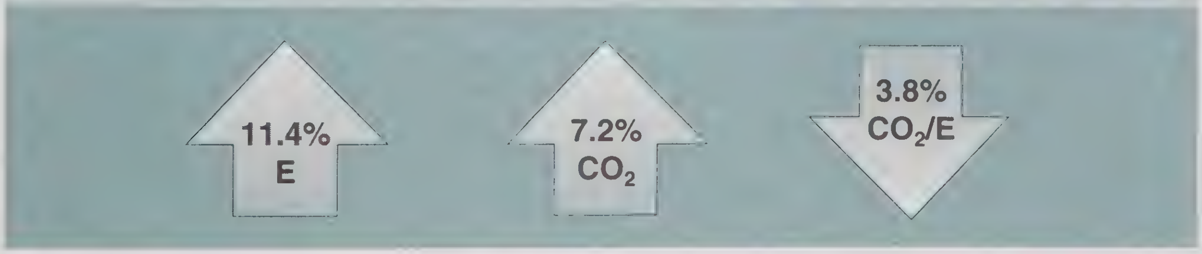
Appendix E presents the analytical framework for examining greenhouse gas emission trends, and Appendix F defines the technical terms used in the report.

This report describes only part of the data and indicators collated for the analysis. All of the data prepared for this report is available on the Internet at the following address: **http://oee.nrcan.gc.ca/general/trends/index_e.htm**

Economy-Wide Trends in End-Use Energy, Energy Efficiency and Emissions

HIGHLIGHTS

- Over the 1990 to 1996 period, secondary energy use (E) increased by 11.4 percent, or by 782 petajoules.
  - Increases in activity in the five major energy-using sectors caused energy use to increase. In the absence of activity growth from 1990 to 1996, energy use would have been 714 petajoules lower in 1996 than it actually was.
  - The change in the mix of activity towards more energy-intensive segments also contributed to the increase in energy use. In the absence of a change in the mix of activity, energy use would have been 207 petajoules lower in 1996 than it actually was.
  - Colder weather in 1996 compared to 1990 led to higher energy use. Had weather been the same in 1996 as it was in 1990, energy use would have been 130 petajoules lower in 1996 than it actually was.
  - Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1996. Had all other factors remained constant over the period and only energy intensity changed, secondary energy use would have decreased by 247 petajoules from its 1990 level.
- Carbon dioxide emissions (CO_2) resulting from secondary energy use increased by 7.2 percent from 1990 to 1996, as the impact of increased growth in energy use more than offset the decline in the average greenhouse gas intensity of energy use.
- The carbon dioxide intensity of secondary energy (CO_2/E) use decreased by 3.8 percent from 1990 to 1996 due to a shift towards the use of fuels with a lower carbon dioxide content and a decline in carbon intensity. In the absence of this fuel shift, carbon dioxide emissions would have been 16.7 megatonnes higher in 1996 than they actually were.



In 1996, secondary energy use accounted for about 70 percent of the total energy requirements in Canada. At the secondary level, energy is consumed in five sectors: residential, commercial, industrial, transportation and agricultural. The industrial sector accounts for the largest share of secondary energy use (38.3 percent), followed by the transportation (26.6 percent), residential (19.0 percent), commercial (13.1 percent) and agricultural (2.9 percent) sectors.

Table 2.1 Sectoral Energy Distribution and Associated Carbon Dioxide Emissions in 1996

SECTORS	Energy Use (petajoules)	Carbon Dioxide Emissions (megatonnes)
Residential	1453	71.2
Commercial	1000	51.6
Industrial	2926	138.8
Transportation	2029	139.9
Passenger	1317	89.8
Freight	651	45.6
Off Road	64	4.4
Agriculture	224	14.3
Total	7632	415.9

Table 2.1 shows the sectoral energy[1] distribution and associated carbon dioxide emissions in 1996. Transportation and agricultural emissions shares are larger than the energy use shares of these sectors because they use a higher concentration of carbon dioxide-intensive energy forms. The transportation and industrial sectors account for the largest shares of carbon dioxide emissions from secondary energy use (33.6 and 33.4 percent, respectively), followed by the residential (17.1 percent), commercial (12.4 percent) and agricultural (3.4 percent) sectors.

As defined in the first chapter, the sectoral review of changes in carbon dioxide emissions presented in this report incorporates electricity end-use related emissions, which are defined as secondary energy use-related emissions. Electricity end-use consumption is attributed an emissions factor reflecting the average mix of fuels used to generate electricity.

Table 2.2 provides an overview of sectoral activity growth, resulting secondary energy use and corresponding carbon dioxide emissions growth over the 1990 to 1996 period for the five end-use sectors.

Secondary energy demand grew by 11.4 percent, from 6850 petajoules to 7632 petajoules. Energy use grew by at least 12.0 percent in the residential and commercial sectors. Growth in energy use was slightly less in the industrial, transportation and agricultural sectors at 11.8 percent, 10.2 percent and 9.3 percent, respectively.

Table 2.2 Sectoral Activity, Energy Use and Carbon Dioxide Emissions Growth, 1990–1996 (percent)

SECTORS	Activity	Energy Use	Carbon Dioxide Emissions
Residential	11.9	12.3	6.2
Commercial	11.0	12.0	4.9
Industrial	6.5	11.8	5.6
Transportation		10.2	10.2
Passenger	17.8	9.8	9.8
Freight	14.7	11.0	11.0
Agriculture	34.9	9.3	8.0

1 The definition of energy use included in each of the sectors for the purpose of this report is documented in Appendix C. These definitions are different from the sectoral definitions adopted by Environment Canada in *Trends in Greenhouse Gas Emissions 1990–1995*. Definitional differences between this report and Environment Canada's report and their implications for the level of emissions for each sector are documented in Appendix D.

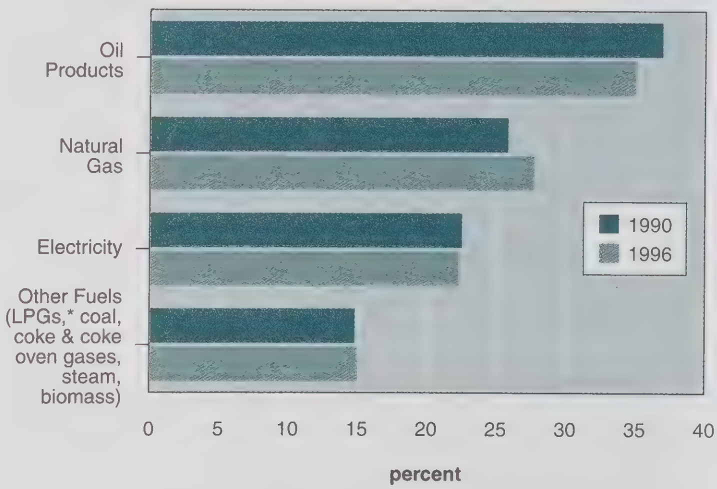
From 1990 to 1996, activity growth was highest in the agricultural sector with 34.9 percent growth, followed by passenger and freight transportation (17.8 and 14.7 percent, respectively), residential (11.9 percent), commercial (11.0 percent) and industrial (6.5 percent). Activity growth was the main driver of energy demand growth. The difference between activity and energy growth reflects the influence of other factors that include changes in a) energy efficiency (for the purpose of this report energy intensity is used as a proxy for energy efficiency); b) weather; and c) the mix of activity within a sector. The influence of these factors on the change in energy use is discussed in detail in Chapters 3 to 7.

Energy-related carbon dioxide emissions increased by 7.2 percent, or 28 megatonnes from 388 megatonnes in 1990 to 416 megatonnes in 1996. The most significant change occurred in the transportation sector, where emissions increased by 10.2 percent, or close to 13 megatonnes, over the period. Agricultural sector emissions increased by 8.0 percent over the period, followed by residential (6.2 percent), industrial (5.6 percent) and commercial (4.9 percent).

Carbon dioxide emissions are the combined result of energy use and fuel mix, which defines the carbon dioxide intensity per unit of energy. From 1990 to 1996, the carbon dioxide intensity of secondary energy consumption decreased from 56.6 to 54.5 tonnes per terajoule. About one-third of this 3.8 percent decrease in carbon dioxide intensity reflects a fuel shift from oil products to natural gas, and about two-thirds of the decline reflects a change in the mix of fuel used for electricity generation. As shown in Figure 2.1, from 1990 to 1996, the share of natural gas increased by 1.9 percentage points while other fuels increased by 0.3 percentage points (mostly wood waste and pulping liquor used in the pulp & paper sector), mainly at the expense of oil products. As the carbon dioxide intensities of natural gas and wood waste are lower than those of most oil products, fuel switching contributed to a reduction in carbon dioxide emissions over the 1990 to 1996 period.

Changes in the fuel mix for electricity generation had a downward influence on global carbon dioxide intensity. The carbon dioxide intensity of electricity declined from 55.9 tonnes per terajoule in 1990 to 49.2 tonnes per terajoule in 1996. In 1996, electricity generation was slightly less carbon-intensive than natural gas end-use. The decline in the carbon dioxide intensity of electricity generation was due to a shift from coal and heavy fuel oil to nuclear and natural gas. This contributed to a reduction in the carbon dioxide intensity of secondary energy use and, subsequently, to reduced growth in emissions. Had electricity-related carbon dioxide emissions not been included, secondary energy end-use emissions would have increased by over 30 megatonnes (from 302 Mt in 1990 to 333 Mt in 1996), which would have represented an increase of 10.1 percent for the period.

Figure 2.1 Secondary Energy Fuel Shares, 1990 and 1996 (percent)



* liquefied petroleum gases

2.1 Evolution of Secondary Energy Use and its Major Determinants

Table 2.3 presents the effect of growth in activity, structure, weather and energy intensity on the growth in secondary energy use from 1990 to 1996. A fifth factor, the interaction effect, is also shown in Table 2.3. This factor results from the interaction between the four other factors and is explained in the section titled "Note on Interaction Terms" in Appendix B.

Data in Table 2.3 shows that growth in secondary energy use was most influenced by growth in sectoral activity levels. Had only the level of activity changed in each sector from 1990 to 1996 while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 714 petajoules, rather than the actual 782 petajoules.

Structure, or the mix of activity, also contributed to the increase in secondary energy use since 1990. Structural change over this period favoured a shift in the distribution of sector activity towards more energy-intensive components of the Canadian economy. This shift contributed 207 petajoules to the increase in secondary energy use.

Weather also contributed to the increase in secondary energy use. The winter of 1996 was significantly colder than 1990, which increased space-heating requirements by 130 petajoules.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1996. Had energy intensity remained at its 1990 level and only activity levels, structure and weather changed, secondary energy use would have been 247 petajoules higher in 1996 than it actually was.

Table 2.3 Factors Influencing Growth in Secondary Energy Use, 1990–1996 (petajoules)

	Energy Use			Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction Effect	Other
	1990	1996	1996 less 1990 (6)						
Residential	1294	1453	159	153.4	8.7	86.8	-81.6	-8.6	n.a.
Commercial (1)	893	1000	107	97.0	1.0	43.6	-32.9	-0.8	-0.6
Industrial	2618	2926	309	171.2	99.8	n.a.	35.4	2.1	n.a.
Transportation	1840	2029	188	292.6	97.7	n.a	-167.6	-31.6	-3.0
Passenger (2)	1197	1314	117	206.3	9.6	n.a.	-76.8	-12.9	-9.3
Freight (3)	586	651	64	86.3	88.1	n.a	-90.7	-18.7	-0.7
Off-Road Motor Gasoline (4)	57	64	7	n.a.	n.a.	n.a.	n.a.	n.a.	7.0
Agriculture (5)	205	224	19	n.a.	n.a.	n.a.	n.a.	n.a.	19.1
Total	6850	7632	782	714	207	130	-247	-39	15

(1) The factorization excludes street lighting. The change in energy use for this component from 1990 to 1996 is shown in the "Other" column.
(2) The factorization was done using motor gasoline equivalency for alternative transportation fuels and excludes the non-airline (commercial/institutional and public administration) air sector. The difference in energy use for the non-airline component (-8.3 pj) and motor gasoline equivalency for alternative transportation fuels (1.0 pj) is shown in the "Other" column.
(3) The factorization was done using motor gasoline equivalency for alternative transportation fuels. The difference in energy use due to the use of motor gasoline equivalency for alternative transportation fuels (0.7 pj) from 1990 to 1996 is shown in the "Other" column.
(4) The factorization analysis was not done for off-road motor gasoline. The change in energy use for this component from 1990 to 1996 is shown in the "Other" column.
(5) The factorization analysis was not done for the agricultural sector. Chapter 7 shows an aggregate analysis of the sector. The change in energy use for this component from 1990 to 1996 is shown in the "Other" column.
(6) The change in energy use between 1990 and 1996 shown in this column and the sum of activity, structure, weather, energy intensity and interaction for passenger and freight transport are slightly different because of i) the exclusion from the factorization analysis of the non-airline segment in passenger transport and ii) the fact that the factorization of energy use for these sectors was done using motor gasoline equivalency values (see Chapter 6 footnotes for more detail). The transport sector differences are reflected at the secondary energy use level; other differences excluded from the factorization such as agriculture, off-road motor gasoline and street lighting are included under "Other."

Chapters 3 through 7 review sectoral trends in energy use, activity, mix of activity (structure) and energy intensity.

2.2 Trend in the Carbon Dioxide Intensity of Secondary Energy Use

Table 2.4 summarizes the changes in carbon dioxide emissions, energy use and the carbon dioxide intensity of energy use from 1990 to 1996. The change in carbon dioxide emissions is the result of a change in energy use and its carbon dioxide intensity. As discussed earlier, electricity end-use is attributed an emissions factor reflecting the average mix of fuels to generate electricity.

The influence of increased energy use on the growth in emissions was partly offset by a decline in carbon dioxide intensity. In the absence of a decline in the carbon dioxide intensity of secondary energy use, emissions would have been 11.4 percent higher than the 1990 level, or 16.3 megatonnes higher in 1996 than they actually were. The decline in carbon dioxide intensity resulted from a shift in the mix of fuels used to meet end-use demand, including the change in the mix of fuels used for the generation of electricity. Sectoral explanations of the reasons underlying the shift in fuel mix at the secondary level are presented in Chapters 3 through 7.

Table 2.4 Factors Influencing Growth in Carbon Dioxide Emissions from Secondary Energy Use, 1990–1996

	Carbon Dioxide Emissions (megatonnes)		Carbon Dioxide Emissions	Energy Use	Carbon Dioxide Intensity of Energy Use
			(percent change) 1990–1996		
	1990	1996			
Residential	67.0	71.2	6.2	12.3	-5.4
Commercial	49.2	51.6	4.9	12.0	-6.5
Industrial	131.4	138.8	5.6	11.8	-5.5
Transportation	127.0	139.9	10.2	10.2	-0.1
Agriculture	13.3	14.3	8.0	9.3	-1.3
Total	387.9	415.9	7.2	11.4	-3.8

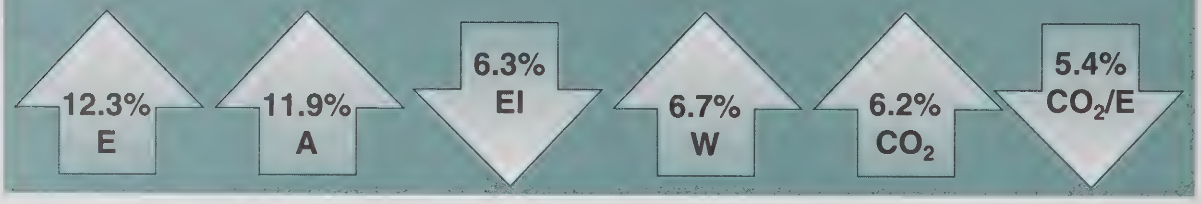
From 1990 to 1996, carbon dioxide emissions related to secondary energy use increased by a total of 7.2 percent, from 388 megatonnes to 416 megatonnes. Energy use had the largest influence on the change in emissions. At the total secondary level, energy use grew by 11.4 percent, from 6850 petajoules to 7632 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 43 megatonnes lower in 1996 than they actually were.

Residential Sector

HIGHLIGHTS

- From 1990 to 1996, residential sector energy use (E) increased by 12.3 percent, or 159 petajoules. Growth in residential energy use was mainly influenced by changes in economic activity (A), energy intensity (EI) and weather (W).
  - Residential sector activity (measured as the growth in households) increased by 11.9 percent. Had all other factors remained constant over the period and only activity changed, residential sector energy use would have increased by 153 petajoules.
  - Colder weather in 1996 compared to 1990 led to an increase in space heating requirements. Had all factors but weather remained at their 1990 level, space heating energy use would have increased 87 petajoules.
  - Aggregate energy intensity (E/A) increased 0.4 percent; however, energy intensity (EI) adjusted for weather and structure declined by about 6.3 percent. Had all other factors remained constant over the period and only energy intensity changed, residential sector energy use would have decreased by 82 petajoules.
- Residential sector-related carbon dioxide emissions (CO_2) increased by 6.2 percent from 1990 to 1996, largely due to growth in energy use while fuel switching helped to mitigate emissions growth.

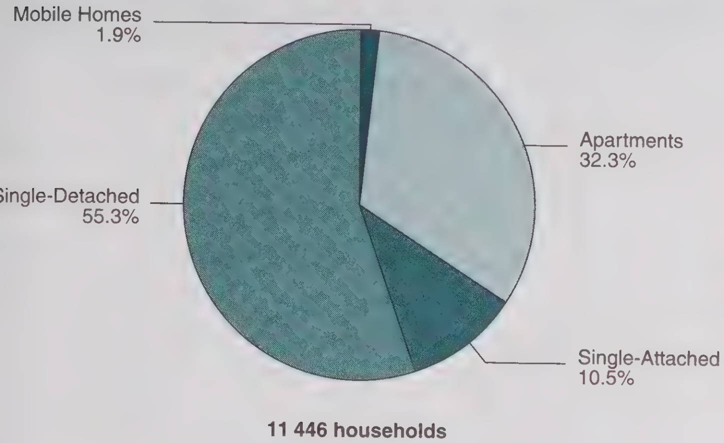
THE ENERGY EFFICIENCY/EMISSIONS BAROMETER—RESIDENTIAL SECTOR



In 1996, residential energy use was 1453 petajoules, which accounted for 19.0 percent of secondary energy demand in Canada. Residential sector-related carbon dioxide emissions were 71.2 megatonnes of carbon dioxide, which represented 17.1 percent of secondary energy-related emissions.

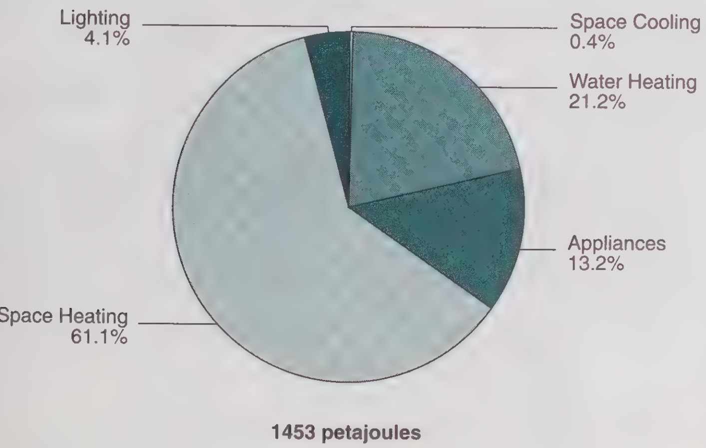
The residential sector comprises four major types of dwellings: single-detached, single-attached, apartments and mobile homes. As shown in Figure 3.1, single-detached homes continue to be the predominant dwelling type accounting for more than half of the total number of residential dwellings.

Figure 3.1 Distribution of Households by Type of Dwelling, 1996 (percent)



Space heating and cooling, water heating, appliances and lighting are the major end-uses of energy in Canadian dwellings. As shown in Figure 3.2, 82.3 percent of the energy demand is used for space and water heating energy requirements. Energy used for appliances and lighting account for an additional 17.3 percent of total residential energy demand.

Figure 3.2 Distribution of Residential Energy Use by End-Use, 1996 (percent)



The main energy sources used by Canadian households are natural gas and electricity. Natural gas accounts for 47.9 percent of total residential energy demand, while electricity and oil account for 33.9 percent and 10.9 percent of residential energy demand, respectively.

Energy source varies according to the end use employed. Natural gas is the main energy source for space heating and water heating, while most appliances are operated with electricity.

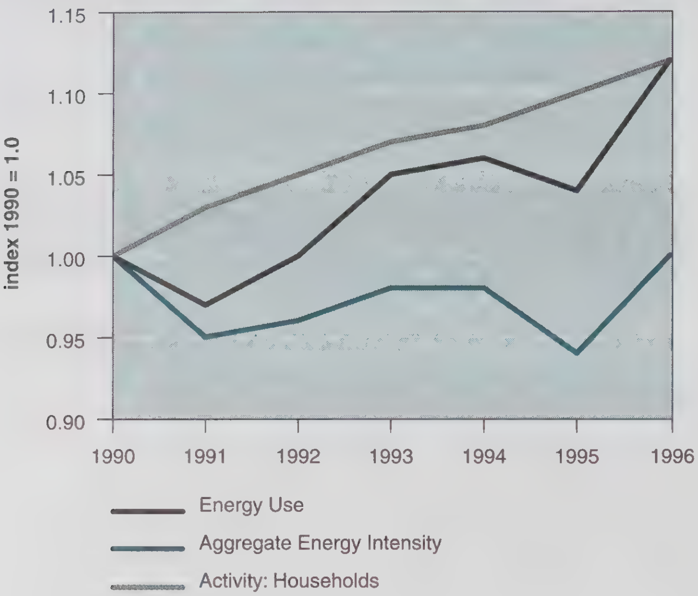
3.1 Evolution of Residential Energy Use and its Major Determinants

Figure 3.3 illustrates the evolution of residential energy use, aggregate energy intensity and activity from 1990 to 1996. Residential energy use increased by 12.3 percent from 1294 petajoules in 1990 to 1453 petajoules in 1996. Of this 12.3 percent increase, 7.5 percentage points are due to an increase in space heating energy demand, 3.6 percentage points are due to an increase in water heating energy use and an additional 0.6 percentage points are due to an increase in appliance energy use. The remaining increase is attributed to lighting energy use.

Household growth is the key driver of residential energy demand. As shown in Figure 3.3, the trend in residential energy use from 1990 to 1996 was strongly influenced by the trend in activity, which is defined as the growth in the number of households. Over the 1990 to 1996 period, approximately 1 million new households were created in Canada, accounting for about a 12.0 percent increase in residential housing stock.

Aggregate energy intensity increased 0.4 percent between 1990 and 1996. Weather is a major determinant of the year-to-year variations in household energy use. The winter of 1996 was colder than the winter of 1990. Weather- and structure-adjusted energy intensity show a decline of 6.3 percent between 1990 and 1996.

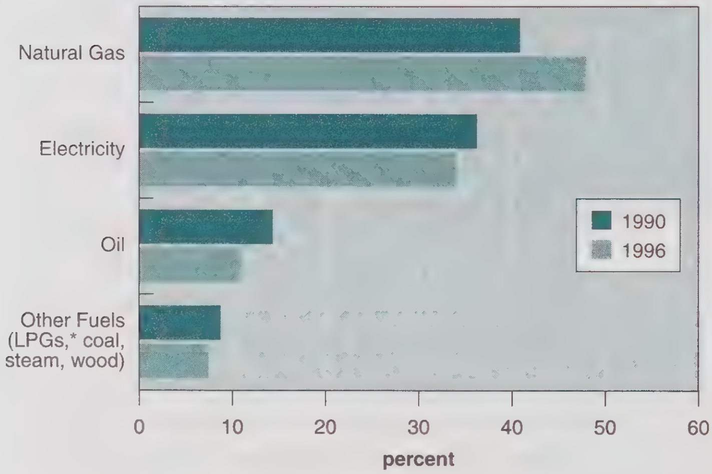
Figure 3.3 **Residential Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990=1.0)**



Changes in Fuel and End-Use Shares

As illustrated by Figure 3.4, the most notable fuel share changes over the 1990 to 1996 period concerned the shift away from oil, which decreased 3.4 percentage points, to natural gas, which increased 7.1 percentage points.

Figure 3.4 **Residential Energy Fuel Shares, 1990 and 1996 (percent)**



* liquefied petroleum gases

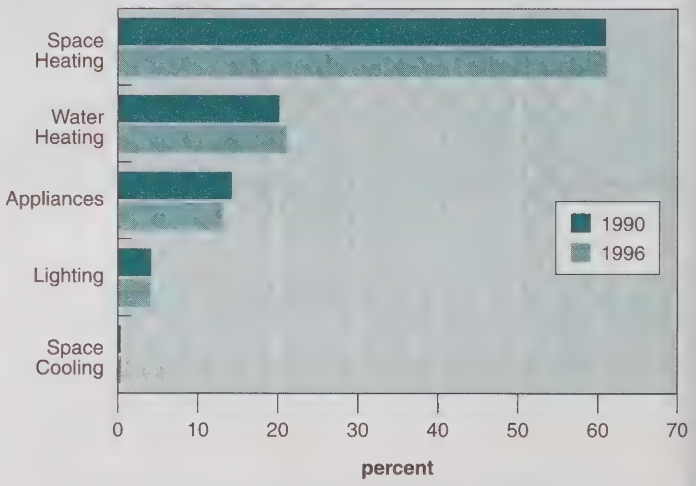
The share of natural gas increased 7.1 percentage points for space heating and 9.8 percentage points for water heating. These increases were largely in response to the wider availability of natural gas and lower natural gas prices. Oil for space heating fell 4.4 percentage points from 1990 to 1996.

The share of electricity decreased by 2.3 percent over the period. The decline in the share of electricity was predominantly in space and water heating. The use of electricity for space heating decreased by a half a percentage point whereas for water heating it has declined by almost 6.7 percentage points.

Figure 3.5 illustrates the end-use shares for 1990 and 1996. Space heating continues to be the single largest end-use with a share of 61 percent in 1990 and 1996.

Water heating increased its end-use share over the period in response to the increased penetration of appliances, particularly hot water using appliances such as dishwashers and clothes washers. For example, the penetration rate of dishwashers increased 6 percentage points over the period.

Figure 3.5 **Residential Energy End-Use Shares, 1990 and 1996 (percent**

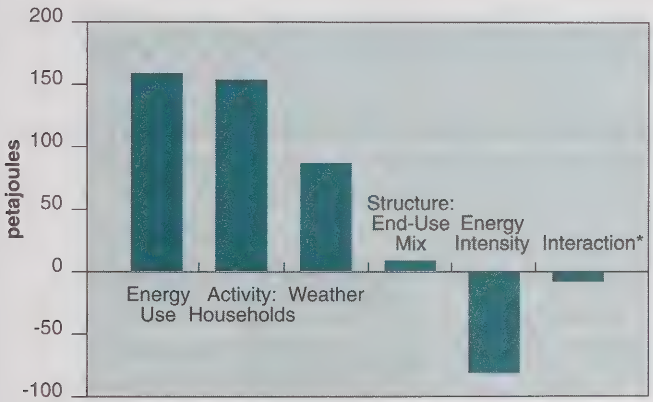


3.1.1 Factors influencing growth in total residential energy use

This section uses the factorization method described in Chapter 1 to separate the influence of activity, structure, weather and intensity on the change in energy use between 1990 and 1996.

Figure 3.6 illustrates the source of growth in total residential energy use from 1990 to 1996. Residential energy use rose by 159 petajoules between 1990 and 1996. The level of *activity* (measured as the number of households[1]) had the largest influence on energy use during this period. In fact, had all other factors — energy intensity, weather and structure — except activity remained constant at their 1990 levels, then residential energy use would have increased by 153 petajoules.

Figure 3.6 Factors Influencing Growth in Residential Energy Use, 1990—1996 (petajoules)



* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

Weather had an important impact on the growth in energy use (87 petajoules). The 1996 heating season was colder than the 1990 heating season, resulting in an increase in energy demand for space heating. Heating degree-days were about 550 degree-days higher in 1996, an increase of about 13.7 percent over 1990. The trend in weather also affected the energy requirement for space cooling. Less energy was used for space cooling as the summer of 1996 was colder than 1990.

The structure (end-use mix) of residential energy use changed little between 1990 and 1996. Although the proportion of households requiring central space cooling increased from 14.0 percent to 18.6 percent, the relative share of energy use required for space cooling is so small that it had a small effect at the aggregate end-use level. However, the share of appliance energy use rose during the period leading to an increase in residential energy use of about 9 petajoules.

The only factor offsetting the increase in residential energy use was the change in energy intensity. Without this energy intensity decline, energy use would have been 82 petajoules higher than it actually was in 1996.

Of the 82-petajoule energy intensity decline, 75 petajoules are attributed to the decline in space heating energy intensity, 19 petajoules to the decline in appliance energy intensity and 1 petajoule to the decline in lighting and space cooling intensities.

This decline in energy intensity can be explained by factors such as improved thermal efficiency of new and existing housing and efficiency gains in residential space heating equipment and appliances. Next, these key factors influencing the change in residential energy space heating and appliance energy use are discussed in detail.

1 Households include single-detached, single-attached, appartments and mobile homes.

3.1.2 Factors influencing space heating energy

From 1990 to 1996, energy demand for space heating increased by 98 petajoules (see Figure 3.7). This increase can be largely attributed to the growth in activity (measured as the number of households). Had all factors affecting space-heating energy use but activity remained constant from 1990 to 1996, space heating energy use would have increased by 94 petajoules.

Space heating energy use is also sensitive to weather changes. In fact, colder weather contributed to an 87-petajoule increase in residential space-heating energy requirements between 1990 and 1996.

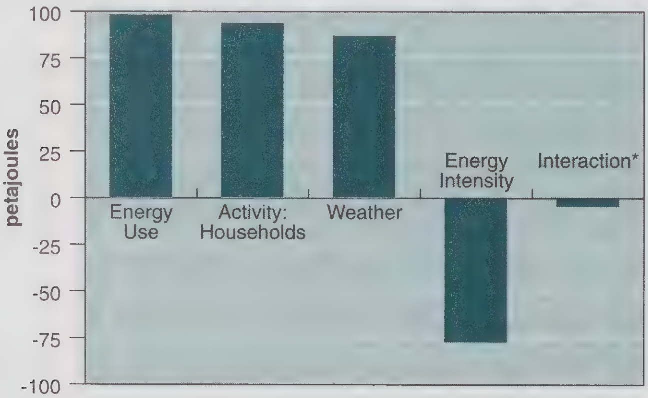
Figure 3.7[2] shows that the increase in space heating energy use due to activity and weather was largely offset by changes in energy intensity. Had all factors affecting space heating energy use remained constant except energy intensity, space heating energy use would have decreased by 78 petajoules from 1990 to 1996.

From 1990 to 1996, space heating energy intensity was affected by improvements in the efficiency of space heating equipment, improvements in the thermal characteristics for new and existing houses, increases in heated living area and decreases in the size of houses. The rest of this section reviews these developments.

Higher Proportion of Newer Homes (stock turnover)

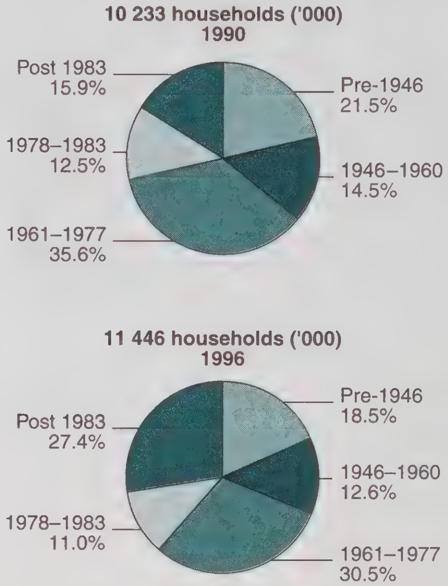
New homes that enter the housing stock tend to be better insulated and usually have more efficient heating equipment. Figure 3.8 shows that the proportion of older homes (pre-1960) in the total stock decreased from almost 36 percent in 1990 to 31 percent in 1996. Meanwhile, the proportion of newer homes (built between 1983 and 1996) increased from 16 percent in 1990 to 27 percent in 1996. The relatively small change in the share of new homes in the total housing stock indicates that it takes time for new housing trends to affect the overall housing stock (slow capital turnover).

Figure 3.7 Factors Influencing Growth in Residential Space Heating Energy Use, 1990–1996 (petajoules)



* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

Figure 3.8 Housing Stock by Vintage, 1990 and 1996 (percent)



2 At this detailed level of end-use disaggregation, it is difficult to identify a structural effect. Unlike appliances, where the mix of equipment involves multiple end-uses (e.g., refrigeration, cooking, etc.), space heating is one end-use. In this regard, structure is not addressed for space heating.

Table 3.1 Thermal Characteristics of Housing Envelope in Canada, 1993 (percentage of households)

	Year of Construction				
	Before 1941	1941–1960	1961–1977	1978–1982	After 1982
Windows					
Triple-Pane	2.9	5.3	6.1	7.4	8.1
Double-Pane	37.2	51.3	59.6	78.8	81.1
Air Exchanger					
Have & Use	4.4	5.0	9.0	10.9	19.9
Heated Basement	48.4	64.5	71.1	74.1	72.1
Exterior Door					
Air leaks	26.6	27.4	24.4	18.0	12.4

Source: *1993 Survey of Household Energy Use*

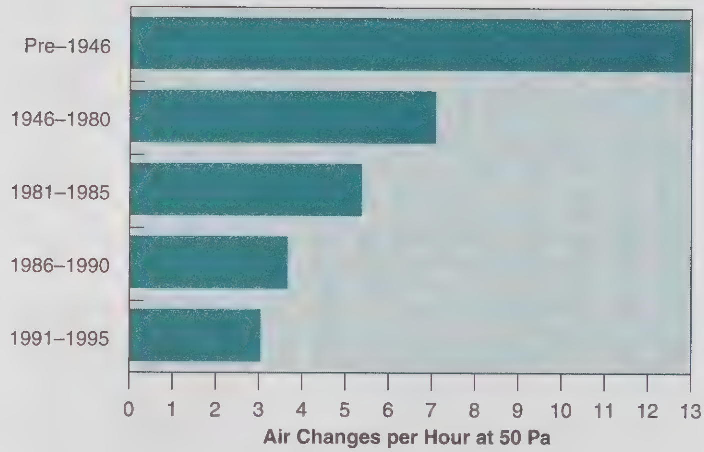
Thermal Shell Improvements - Better Insulated Houses

New Houses

The drop in space heating intensity is also due to the fact that newer houses are built to be more energy-efficient as summarized in Table 3.1.

Homes built more recently are likely to have more efficient windows (summarized above) and will tend to have less air leakage than older houses (see Figure 3.9) . According to the *1993 Survey of Household Energy Use* (SHEU),[3] 26.6 percent of respondents who owned a house built before 1941 reported air leaks around the exterior doors as opposed to only 12.4 percent for respondents owning a house built after 1982. Recently, there are more houses built with double- and triple-pane windows as shown by the table above. These trends have also been confirmed by the results from the *Survey of Houses Built in Canada in 1994* (SHBC).[4] For example, according to SHBC, over 90 percent of respondents owning houses built in 1994 reported to have at least double-pane windows.

Figure 3.9 National Trends in Air Leakage by Vintage (Air changes per hour at 50 Pa)



Existing Stock of Houses

Existing homes are renovated over time. Results from the *1994 Home Energy Retrofit Survey* (HERS)[5] indicate that between 5 percent to 7 percent of homeowners have performed some energy retrofit improvements to their homes each year.

3 Natural Resources Canada, *1993 Survey of Household Energy Use*, Ottawa, Ontario, November 1996.

4 The *Survey of Houses Built in Canada in 1994* was conducted for Natural Resources Canada by Criterion Research Corp. under the National Energy Use Database Initiative. The survey covered about 2300 homeowners across Canada.

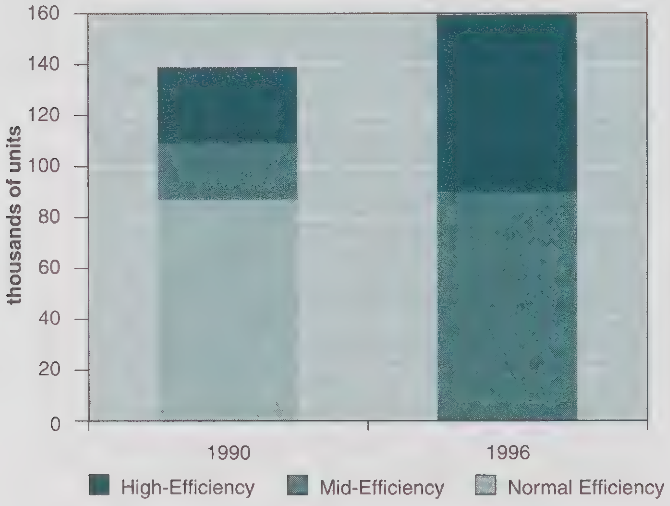
5 This is a supplement to the *Homeowner Repair and Renovation Expenditure Survey in Canada*, 1994.

More Efficient Heating Equipment

Significant efficiency gains in space heating equipment were realized during the 1990–1996 period. The efficiency of new oil and gas space heating equipment, expressed in terms of annual fuel utilization efficiency (AFUE),[6] rose from 63 and 71 in 1990 to 68 and 83 in 1996 for oil and gas furnaces, respectively.

There have been significant changes in the efficiency of oil and natural gas heating equipment from normal efficiency (between 60 percent and 65 percent) to mid-efficiency (78 percent to 83 percent efficient) and high-efficiency (90 percent or more). As shown by Figure 3.10, there is a trend toward more efficient units in the Canadian shipments of natural gas furnaces. In 1996, conventional natural gas furnaces (normal efficiency furnaces) were no longer sold in Canada, leaving the new sales market to only mid- and high-efficiency units.

Figure 3.10 Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1996 (thousands of units)



The higher efficiency of new furnaces has led to an increase in the stock efficiency from 64 percent in 1990 to 66 percent in 1996 for gas heating systems and from 60 percent in 1990 to 61 percent in 1996 for oil heating systems. The slower increase in stock efficiency relative to the increase in the efficiency of new equipment being sold reflects the time it takes for the stock to be replaced by new products.

During the last six years, the efficiency of new heating equipment has reduced space heating energy requirements. If this change had not occurred, space heating energy use would have increased by an additional 92 petajoules.

Larger New Houses

New homes are larger than those built in the past, which means higher space and cooling energy requirements. This trend was confirmed by the results of the 1993 Survey of Household Energy Use and the Survey of Houses Built in Canada in 1994. The increase in size is not surprising given the increased prevalence of single homes, which tend to be larger than apartments and mobile homes. The average single-detached home is about 1375 square feet, while a single-attached home is 1116 square feet compared to the average apartment which is about 861 square feet or a mobile home, which is even smaller.

As shown in Figure 3.1, the share of single-attached homes rose from 8.7 percent in 1990 to 10.5 percent in 1996, while the share of single-detached homes remained about the same level (55.3 percent). The share of single dwellings (detached and attached) increased by about one percentage point, which partly explains the increase in the average size of houses. Even though the share of single-detached homes remained relatively constant, the average heated area of newer detached homes tends to be larger.

6 Fuel-fired furnace efficiency is determined from standardized testing procedures that simulate seasonal performance. This measure of efficiency is the Annual Fuel Utilization Efficiency (AFUE), which is expressed as a percent. Electric resistance heating equipment is assumed to have an AFUE of 100 percent.

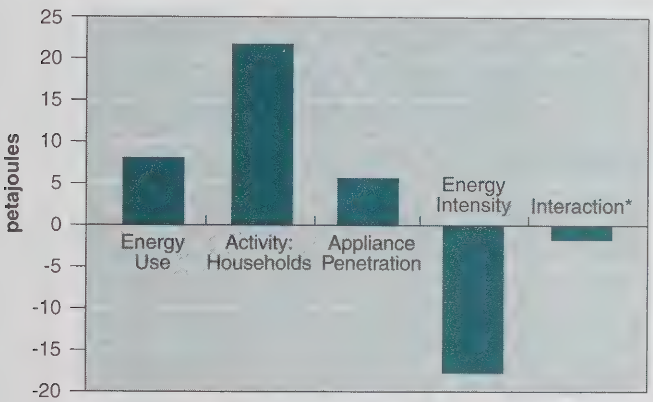
Fuel Switching

As discussed, there has been fuel switching away from oil to natural gas and electricity. For example, natural gas' share increased from 41 percent in 1990 to 48 percent in 1996. The increased share of natural gas and electric furnaces, which have higher average energy efficiency ratings, contributed to the overall decline of space heating energy intensity.

3.1.3 Factors influencing appliance energy use

Energy use by appliances increased by 8 petajoules from 1990 to 1996. Figure 3.11 shows the factors that influenced this increase.

Figure 3.11 Factors Influencing Growth in Residential Appliance Energy Use, 1990–1996 (petajoules)

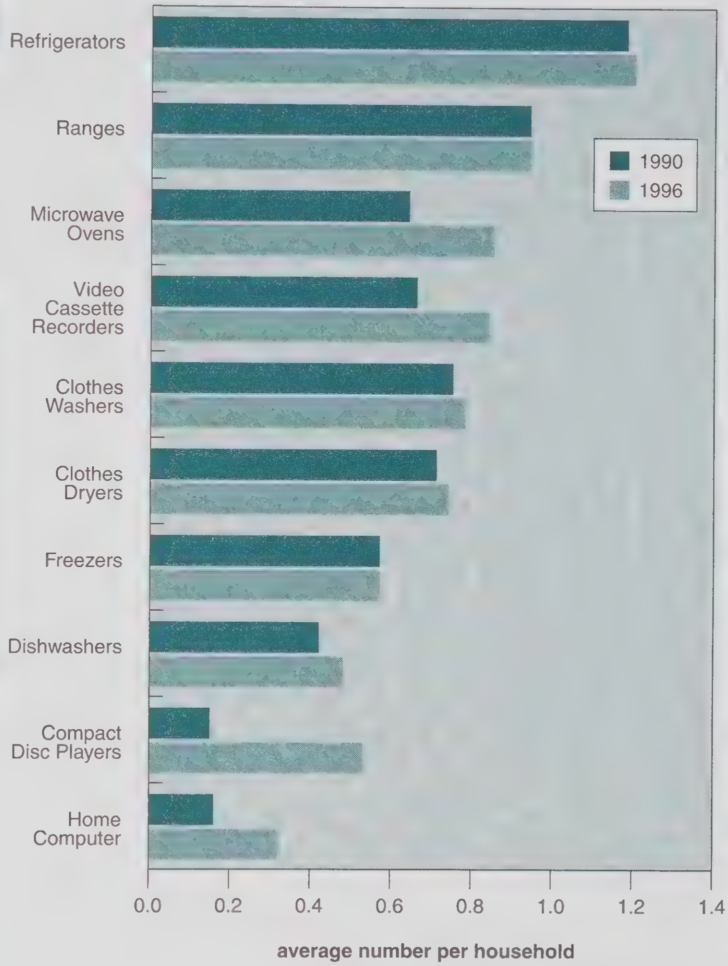


* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

The increase in appliance energy use can be explained by the growth in two factors. The first factor, activity (the number of households), increased appliance energy use by about 22 petajoules. The second factor, structure (the penetration of appliances), increased appliance energy use by about 6 petajoules.

Figure 3.12 illustrates the penetration rates of ten appliances for the years 1990 and 1996. The most significant increase in penetration rates for major appliances were dishwashers and clothes dryers. The share of households with dishwashers increased from 42 percent in 1990 to 47 percent in 1996, while clothes dryers increased from 73 percent in 1990 to 76 percent in 1996. Although to a lesser extent, clothes washers and refrigerators have also increased their share over the period 1990 to 1996. The share of households having two or more refrigerators increased from about 18 percent in 1990 to 20 percent in 1996.

Figure 3.12 Penetration Rates for Household Appliances, 1990 and 1996 (average number per household)



Increasing availability and marketing of new, electricity-consuming devices has increased appliance energy consumption. New equipment includes everything outside the six major "white" goods, space heating, water heating and air conditioning. Among these recent market entrants, compact disc players, home computers and video cassette recorders showed the largest penetration rate increase from 1990

to 1996. In 1990, only 16 percent of Canadian households had a home computer. By 1996, home computers were present in 32 percent of all households. In 1990, only 15 percent of households had compact disc players. By 1996, 53 percent of households had compact disc players. The share of households with video cassette recorders was about 66 percent in 1990. By 1996, that proportion had increased to over 98 percent.

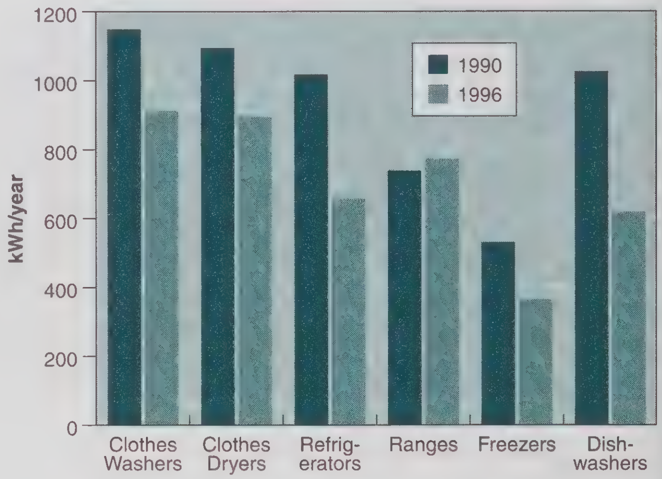
There has also been rapid growth in the penetration rate of microwave ovens. The percentage of Canadian households with microwave ovens has increased from 64 percent in 1990 to 85 percent in 1996. Microwaves use less energy for heating foods.[7] According to results from SHEU (1993), two-thirds of households that have a microwave use it everyday to reheat food.

Many of these "miscellaneous" appliances are competing with the refrigerator for the position of the number one energy consumer. Aquariums, terrariums, waterbeds and swimming pool pumps all have the potential to consume large quantities of energy. According to a study conducted by the Canadian Residential Energy End-Use Data and Analysis Centre (CREEDAC),[8] these miscellaneous users of energy accounted for 1300 kWh per year per household in 1993, which is equivalent to the energy consumed by two new refrigerators.

More efficient appliances

The increase in energy use associated with appliances was partially offset by substantial improvements in their energy efficiency. More efficient appliances have contributed to a decrease in appliance energy use by about 24 petajoules. Figure 3.13 illustrates the change in efficiencies for major new appliances between 1990 and 1996. Over the period, most new appliances such as refrigerators and freezers have become substantially more energy-efficient. By 1996, the average new dishwasher was 40 percent more efficient while new refrigerators and freezers were 35 percent more efficient than their 1990 counterparts (see sidebar, Energy Efficiency Trends for Refrigerators).

Figure 3.13 Energy Efficiency Trends of Appliances, 1990 and 1996 (kWh/year)



More efficient appliances are being built and sales data confirm that the market has been moving toward more efficient appliances (see sidebar, Appliance Market Overview).

7 Heating foods in a microwave requires less energy than using other technologies according to a recent study by the American Council of Energy-Efficiency Economy, Washington DC. See, Alex Wilson and John Morril, *Consumer Guide to Home Energy Savings*, 4th Edition, 1996, p.188.

8 Residential Electrical Energy Use Associated with Miscellaneous Appliances in Canada, CREEDAC, 1996.

Appliance Efficiency Gains

There have been substantial improvements in the efficiency of major appliances from 1990 to 1996. For example, a typical new refrigerator in 1996 consumes less than half the energy of the average refrigerator stock. As shown below, as time passes, Canada's stock of appliances will continue to become less energy-intensive.

Appliance	Appliance Annual Energy Consumption		
	1990 Stock (kWh/Year)	1996 Stock (kWh/Year)	1996 New Unit (kWh/Year)
Refrigerator	1588	1223	660
Freezer	965	824	396
Clothes Washer	1265	1195	1050
Dishwasher	1291	1048	700
Electric Clothes Dryer	1317	1162	744

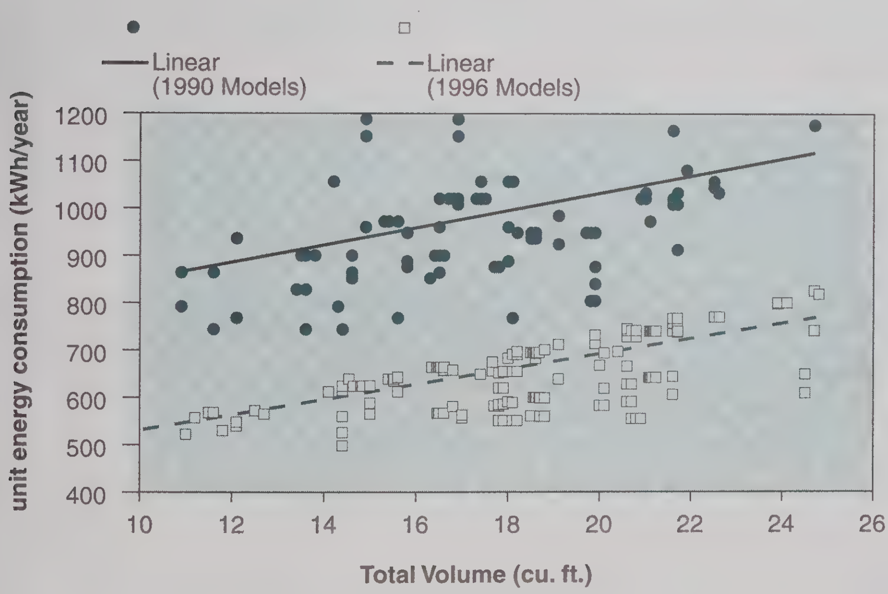
Sources: Residential End-Use Model and EnerGuide 1996.

Energy Efficiency Trends for Refrigerators

An average new auto-defrost refrigerator with top-mount freezer used about 1020 kWh per year in 1990 and about 660 kWh per year in 1996. This represents a technical efficiency improvement of about 35%. At the same time, the size of refrigerators, a factor contributing to energy consumption, increased by 16%. Therefore, the gains in efficiency associated with technology improvements have more than offset the increase in energy consumption associated with size.

Appliance Efficiency Gains for Refrigerators

Unit Energy Consumption for Top-Mount Auto-Defrost Refrigerators



An Overview of the Appliance Market

A visual analysis of the data for the four major energy-consuming appliances shows (Figure A) that 1990 models were consuming more energy per unit than the 1996 models. Unit energy consumption per year fell even though the size of some appliances (refrigerators) has increased for the majority of 1996 models. Analysis of sales data (Figure B) confirms that the market (consumer decisions) has been moving toward more efficient appliances. For example, sales-weighted average energy consumption per cubic feet of refrigeration declined from 54 kWh per year in 1992 to 33 kWh per year in 1996 for the most common refrigerators (top-mounted and auto-defrost refrigerator).

FIGURE A

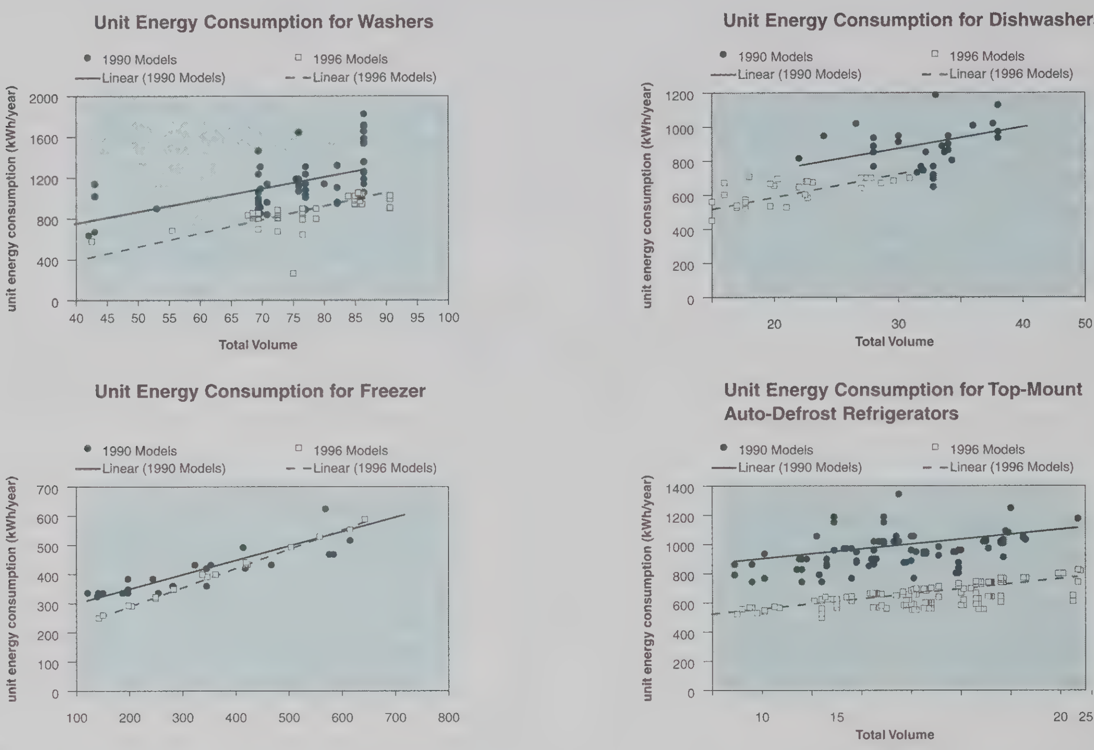
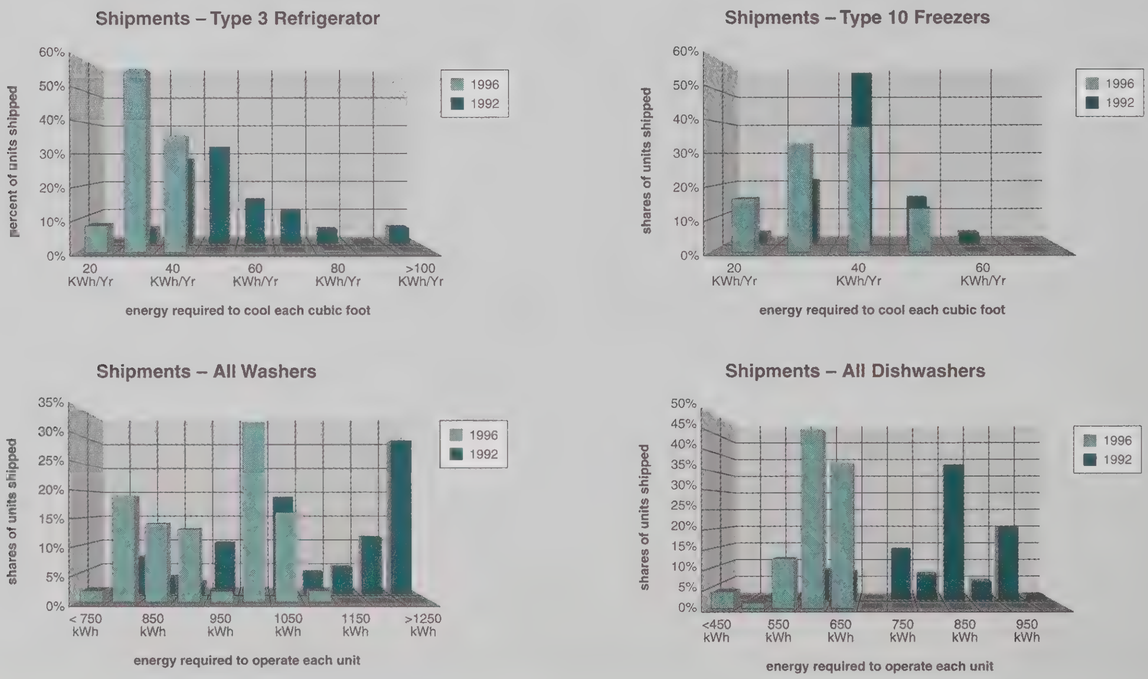


FIGURE B



3.1.4 Factors influencing other end-uses

Water Heating Energy Use

Water heating energy requirements increased by 46 petajoules between 1990 and 1996. About 31 petajoules of this increase can be explained by the increase in the number of households. In addition, more households now have two water-using appliances: a dishwasher and a clothes washer.[9]

The increase in water-heating energy use has been partially offset by efficiency improvements. For example, in 1996, new dishwashers and clothes washers were 40.0 percent and 20.0 percent respectively more efficient than those of 1990 (see Figure 3.13). Furthermore, there has been improvement in the technical efficiencies of new water heaters ranging from 2 to 4 percent for electric, gas and oil water heaters.

At the same time, there was a small decrease in household size, which contributed to mitigate the increase in energy use for water heating and appliance end-uses. The size of households, measured in terms of persons per household, decreased by 3 percent over the period 1990 to 1996 (from 2.88 persons per household in 1990 to 2.80 in 1996).[10]

Space Cooling Energy Use

Energy used in space cooling accounts for less than 1 percent of total residential energy use. However, air conditioners are becoming more common in Canada. The penetration rate of central air conditioners rose from 14 percent of households in 1990 to 19 percent in 1996.

Air conditioning units have become more energy-efficient over the last 10 years. For example, the energy efficiency of new room air conditioners increased 20 percent[11] over the period of 1984-1996 and about 3 percent over the last five years.

Lighting Energy Use

Electricity use for lighting represents about 4 percent of all residential energy demand. The Canadian Residential Energy End-Use Data and Analysis Centre[12] (CREEDAC) has estimated the average annual amount of electricity used for lighting by Canadian households in 1993. Using data on the average number of bulbs per household collected through the SHEU, CREEDAC estimates that the average energy consumption of lighting is about 1767 kWh per dwelling.

The results indicate that incandescent bulbs account for 91 percent of lighting in Canadian households. Fluorescent and halogen lighting are not widely used. The annual electricity

Table 3.2 Lighting Energy Consumption – Canada, 1993

	Bulbs per Household (units)	Average Capacity (Watts)	Average Usage per Bulb (hours/day)	Lighting Use kWh/year /Dwelling
Incandescent	24.6	67.1	2.7	1645.0
Fluorescent	2.2	41.1	3.8	103.4
Halogen	0.4	41.1	3.8	18.5

Source: "Lighting Energy Use in Canada," September 1996, CREEDAC.

9 Approximately 88 percent of the energy used by dishwashers and 92 percent of the energy used by clothes washers heats the water; the remaining energy is used by motors.

10 Statistics Canada, *Household Facilities and Equipment* (Catalogue No. 64-202), Ottawa, Ontario, October 1996.

11 Association of Home Appliance Manufacturers, *Room Air Conditioners: Energy Efficiency and Consumption Trends*, Chicago, Illinois, July 1996.

12 CREEDAC was created under the National Energy Use Database Initiative, a component of Natural Resources Canada's Efficiency and Alternative Energy Program.

consumption per dwelling is estimated at about 1645 kWh for incandescent lighting, 103 kWh for fluorescent lighting and about 19 kWh for halogen lighting.

3.2 Trend in Carbon Dioxide Emissions of Residential Energy Use

As shown in Figure 3.14, residential sector-related carbon dioxide emissions[13] rose from 67.0 megatonnes in 1990 to 71.2 megatonnes in 1996, representing an increase of 6.2 percent over the 1990 level. In 1996, 33.8 percent of residential sector carbon dioxide emissions were indirect emissions, which reflects the relative importance of electricity as an energy source for the residential sector.

The increase in residential carbon dioxide emissions was largely due to growth in residential energy use, which increased by 12.3 percent over the 1990–1996 period.

Figure 3.14 Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector 1990—1996 (percent)

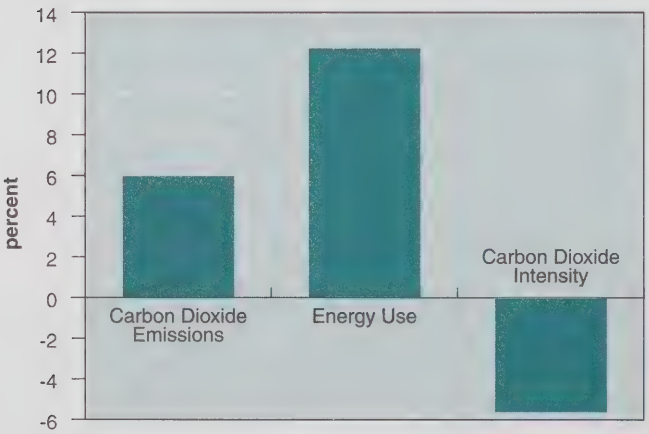
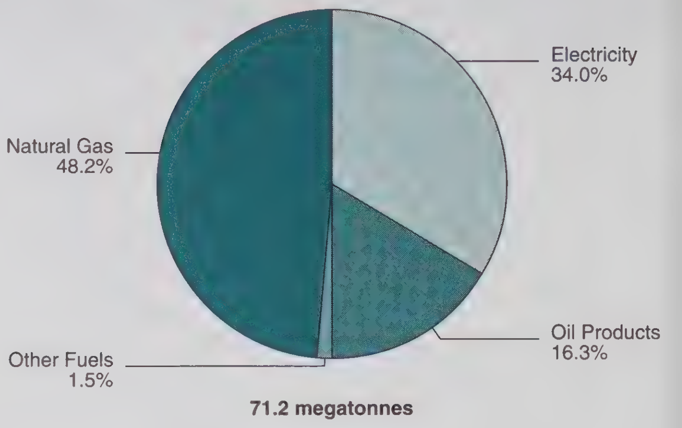


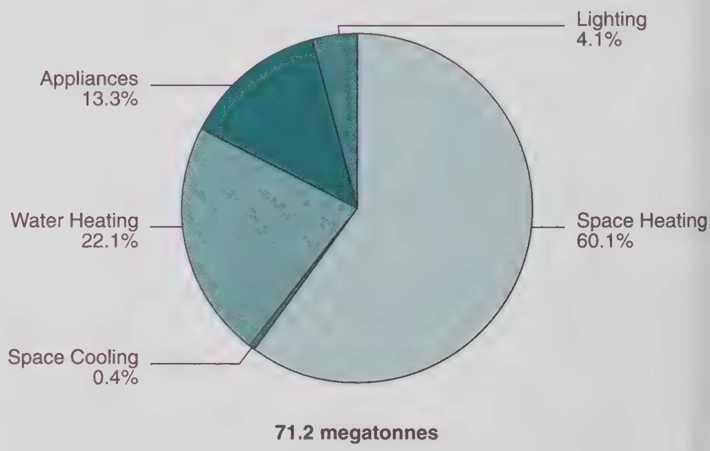
Figure 3.15 shows that close to half of the carbon dioxide emissions (48.2 percent) in the residential sector are attributed to the use of natural gas — the predominant energy source in this sector. Electricity acccounted for 34.0 percent of residential sector emissions.

Figure 3.15 Residential Carbon Dioxide Emissions by Fuel, 1996 (percent)



As shown in Figure 3.16, space and water heating end-uses account for over 80 percent of emissions in the residential sector. Over the 1990–1996 period, emissions from space and water heating increased by 9 and 10 percent, respectively, while emissions associated with appliance use declined by about 8 percent, mainly due to the decline in the carbon intensity of electricity generation-related emissions.

Figure 3.16 Residential Carbon Dioxide Emissions by End-Use, 1996 (percent)



13 The definition of residential energy demand and related carbon dioxide emissions used in this report differs from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990-1995*. See Appendix D for documentation of differences.

Trend in Carbon Dioxide Intensity

Had it not been for the decline in the carbon dioxide intensity of energy use, residential sector emissions would have increased by 12.3 percent rather than 6.2 percent over the period. Average carbon dioxide intensity declined from 51.8 tonnes per terajoule in 1990 to 49.0 tonnes per terajoule in 1996, a decline of about 5.4 percent over the 1990 level. This reflects a number of shifts in end-use fuel shares and a change in electricity generation carbon dioxide intensity.

The principal underlying factor of the decline in carbon dioxide intensity is the trend toward a more "efficient" fuel mix, i.e. switching to fuels such as natural gas with a lower carbon dioxide content, as depicted in Figure 3.4. Another contributing factor to the decline in energy intensity is the decline in the carbon dioxide intensity of the mix of fuel used to generate electricity.

While the share of electricity and fuel oil declined by 2.3 and 3.4 percentage points, respectively, the share of natural gas increased by 7 points. The carbon dioxide intensity of natural gas is lower than the carbon dioxide intensity of oil. The shift towards natural gas was driven by the growth in water heating and space heating requirements.

Over the 1990 to 1996 period, the share of natural gas in water heating energy use increased by about 10 percentage points (from 50.5 percent to 60.3 percent). Similarly, the use of natural gas for space heating energy use increased by 7.9 percentage points (from 49.0 percent to 56.9 percent) at the expense of oil products.

3.3 The Data Situation

In the residential sector, aggregate data on energy use have been reported on a quarterly basis since 1978 in Statistics Canada's *QRESD* (Cat. #57-003). Additional data on the characteristics of residential equipment and housing are collected in the *Household Facilities and Equipment Survey*, which is also undertaken by Statistics Canada.

Additional information has been collected through the National Energy Use Database (NEUD) Initiative. The strategy for developing this additional information involves two types of surveys:

Stock Surveys: These surveys focus on the characteristics of household equipment and building stocks. This part of the strategy was initiated by conducting the 1993 Survey of Household Energy Use which will be repeated in 1998.

Flow Surveys: Separate surveys are carried out to gather information on flow variables affecting the housing stock such as characteristics of new equipment, new housing and retrofit activities. This part of the strategy was implemented by conducting the *Survey of Canadian New Household Equipment Purchases 1994 & 1995*, the Survey of Houses Built in Canada in 1994 (SHBC) and the Home Energy Retrofit Survey (HERS) in 1994 and 1995. NEUD has obtained data on new appliance sales, 1990 to 1996, from the Canadian Appliance Manufacturers Association. NEUD has recently completed a survey on repair and renovation in 1997. The SHBC is expected to be repeated in 1999.

The residential model and database have been improved in three areas:

- dual space heating systems now include the gas/electric type;
- the weather elasticity of space heating has been revised; and
- regional, rather than a national, water heating loads are now used.

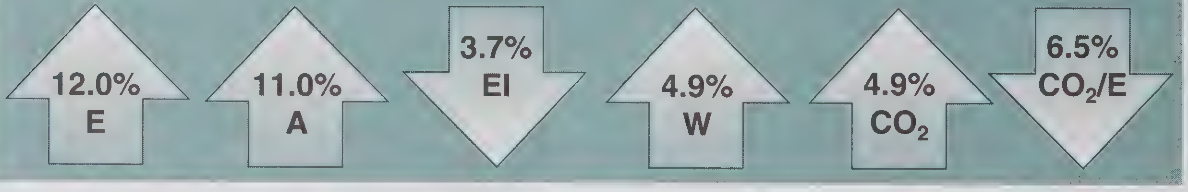
Chapter 4

Commercial Sector

HIGHLIGHTS

- From 1990 to 1996, commercial sector energy use (E) increased by 12.0 percent, or 108 petajoules. Growth in energy use was influenced by changes in activity (A), the mix of activity, weather (W) and energy intensity (EI). The impact of these factors was the following:
  - Commercial activity (measured by floor space) increased by 11.0 percent. Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by 97 petajoules.
  - Fluctuation in climatic conditions also had an upward influence on energy use. Had all factors but weather conditions remained at their 1990 level, energy use would have increased by 44 petajoules.
  - The change in the distribution of floor space marginally influenced commercial energy use. Had all other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only one petajoule.
  - Aggregate energy intensity (E/A) increased 1.1 percent; however, energy intensity (EI) adjusted for weather and structure declined by 3.7 percent. Energy use would have decreased by 33 petajoules had only energy intensity fluctuated over the period. Energy intensity was the sole factor to mitigate the growth in energy use.
- Carbon dioxide emissions (CO_2) of commercial energy use were 4.9 percent higher in 1996 than in 1990. This increase was caused by the increase in energy use. During the period, the decline in the carbon dioxide intensity (CO_2/E) resulting from the commercial energy use contributed to a reduction in the growth of emissions.

THE ENERGY/EMISSIONS BAROMETER — COMMERCIAL



Commercial energy use in 1996 was 1000 petajoules, accounting for 13.1 percent of secondary energy demand in Canada. Commercial energy use-related emissions accounted for 51.6 megatonnes[1] of carbon dioxide, which represents 12.4 percent of emissions from total secondary energy use-related emissions, mainly from the energy used for space heating.[2]

Among the five sectors studied in this report, energy use data limitations are most significant in the commercial sector. However, efforts are being made to improve the situation as described in section 4.3.

1 The definition of commercial energy demand and related carbon dioxide emissions adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. See Appendix D for further documentation of the Natural Resources Canada adjustments.

2 Street lighting energy use and its related carbon dioxide emissions are excluded from all discussions in the remaining text of this chapter. This component of the commercial sector accounted for 9 petajoules and 0.5 megatonnes of carbon dioxide emissions in 1990 and 8 petajoules and 0.4 megatonnes of carbon dioxide emissions in 1996.

The commercial sector is defined to include activity related to trade, finance, real estate services, public administration, education and commercial services (including tourism). The largest end-use in the commercial sector is space heating, accounting for more than half of total energy use. Lighting was the second largest end-use in 1996, accounting for about 14 percent of commercial energy use, followed by motive power at 12 percent for services such as pumping and ventilation in buildings. Water heating, space cooling, and electric plug load accounted for almost 21 percent of commercial energy use.

In 1996, natural gas and electricity represented about 88 percent of commercial energy use. Oil products accounted for 7 percent, and the balance was shared among liquefied petroleum gases, coal and steam.

The distribution of commercial energy use and activity by building type for 1996 is presented in Figure 4.1. About three-quarters of commercial energy use and floor space is accounted for by retail, office, educational and health buildings. In general, the share of energy use accounted for by individual building types is comparable to their share of activity (floor space). Only in three cases, health facilities, hotels/restaurants and warehouses, is the share of energy use notably different from the share of floor space. In the case of health facilities and hotels/restaurants, the share of energy use is larger that the share of floor space reflecting energy-intensive activity in these sectors. In warehouses, the energy-related services required are minimal.

Figure 4.1 Distribution of Commercial Energy Use and Activity by Building Type, 1996 (percent)

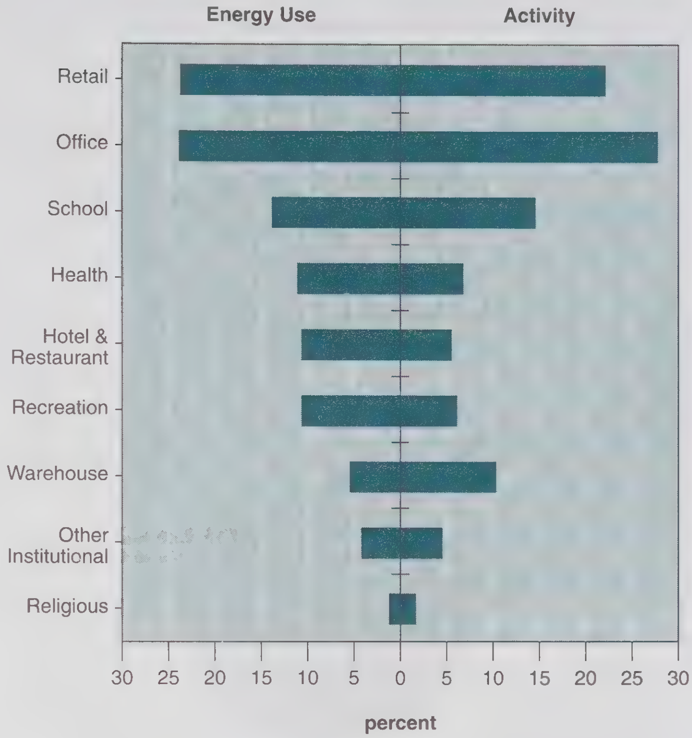
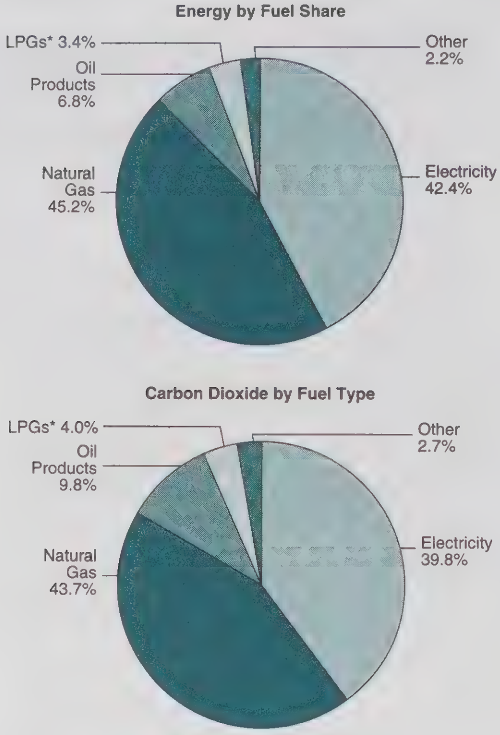


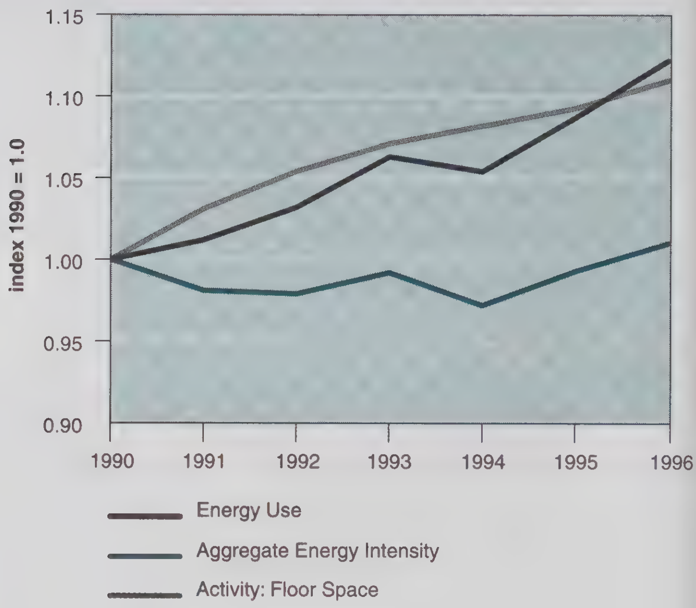
Figure 4.2 presents the contribution of each fuel type to carbon dioxide emissions and commercial energy use in 1996. The carbon dioxide emissions associated with electricity generation are important in the commercial sector since electricity represents more than 40 percent of commercial energy use. Electricity and natural gas accounted for 87.6 percent of energy use, but only 83.5 percent of emissions. It was the opposite for the remaining fuels, particularly for oil products, as their share of emissions was higher than their share of energy use because of the higher carbon dioxide intensity for these energy sources.

Figure 4.2 Energy by Fuel Share and Carbon Dioxide by Fuel Type, 1996 (percent)



*liquefied petroleum gases

Figure 4.3 Commercial Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

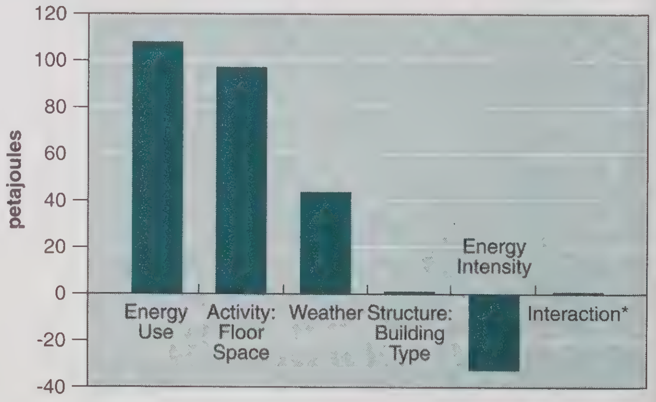


4.1 Evolution of Commercial Energy Use and its Major Determinants

Figure 4.3 illustrates the trends in energy use, activity and aggregate energy intensity from 1990 to 1996. Commercial sector energy use increased by 12.0 percent, or 108 petajoules, from 1990 to 1996. Commercial sector activity (floor area) increased by 11.0 percent, and therefore, aggregate energy intensity increased by 1.1 percent. Aggregate energy intensity did not increase between 1990 and 1994, as shown in Figure 4.3, but slightly declined despite the fact that the weather was putting an upward pressure on energy use over these years. In 1994, aggregate energy intensity was 2.8 percent lower than the 1990 level. Aggregate energy intensity increased in 1995 and 1996 mostly because of the weather.

As mentioned in Chapter 1, the factorization analysis provides an alternative perspective on the changes in energy use in the commercial sector. This approach attributes the changes in energy use over a given time period to activity, structure (measured as mix of building types), weather and energy intensity. The results of the factorization analysis, shown in Figure 4.4, reveal that variations in activity, weather, and energy intensity had a significant effect on the changes in energy use over the 1990–1996 period. Based on this analysis, the mix of activity, or the structure effect, had little influence on the changes in energy use from 1990 to 1996.

Figure 4.4 Factors Influencing Growth in Commercial Energy Use, 1990–1996 (petajoules)



* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

The factorization results for the commercial sector for the period 1990 to 1996 can be summarized as follows:

- Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by 97 petajoules.
- Fluctuation in climatic conditions also had an upward influence on energy use. Had all factors but weather conditions remained at their 1990 level, energy use would have increased by 44 petajoules.
- The change in the distribution of floor space (structure) marginally influenced commercial energy use. Had all other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only one petajoule.
- Had only energy intensity changed over the period of analysis, energy use would have decreased by 33 petajoules.

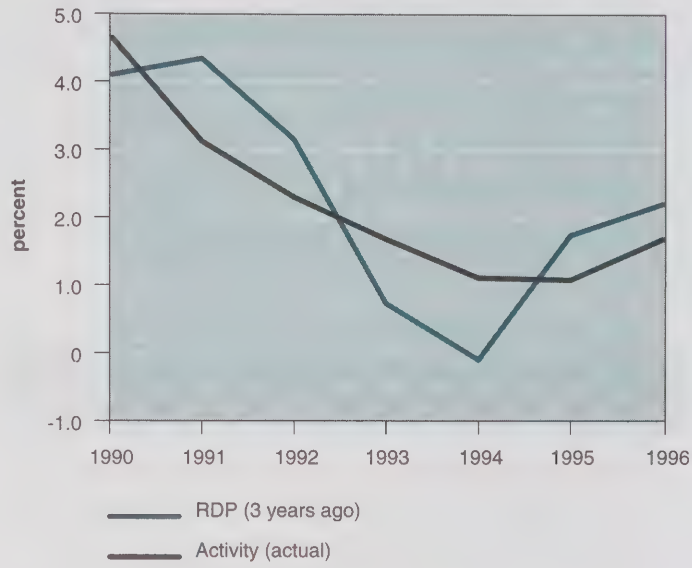
The next four subsections describe some of the factors underlying the activity, weather, structure and energy intensity effects estimated for the commercial sector.

4.1.1 The influence of growth in commercial activity – the activity effect

The factorization results attribute 108 petajoules of the change in energy use from 1990 to 1996 to changes in activity. Activity rose by 51 million square metres, or 11.0 percent, over this period, which is a much lower growth rate than the 31.9 percent increase for the 1984–1990 period.

An important characteristic of the change in the commercial real estate market across Canada is the long construction lag in response to changes in the demand for commercial space. This lag includes the time it takes to conceive, design, obtain approval for, and construct a commercial building. Figure 4.5 shows the annual growth of real domestic product (RDP) in the commercial sector with a three-year lag, as well as the growth in floor space. As illustrated in Figure 4.5, there is a close correlation between growth of RDP in the commercial sector and actual activity when a three-year time lag is taken into account.

Figure 4.5 Annual Growth of Commercial Floor Space and RDP, 1990–1996 (percent)



The addition of new floor space to the stock in 1990 and 1991 was mostly a response to the economic conditions that took place in 1987 and 1988. Since these floor space additions occurred at a time of significant economic downturn, this created an oversupply of floor space, which was gradually brought down in subsequent years, as the real estate market adjusted to the new economic conditions.

Although new floor space was added in the private sector (i.e., office, warehouse, hotel, retail and recreational buildings) and in the institutional sector (i.e., school, health, religious, and other institutional buildings) at similar average annual rates (1.7 percent and 1.9 percent, respectively) during the 1990–1996 period, it was not the case for the previous period. The growth in the private sector was three percentage points above the institutional sector's 2.6 percent average annual growth rate between 1984 and 1990.

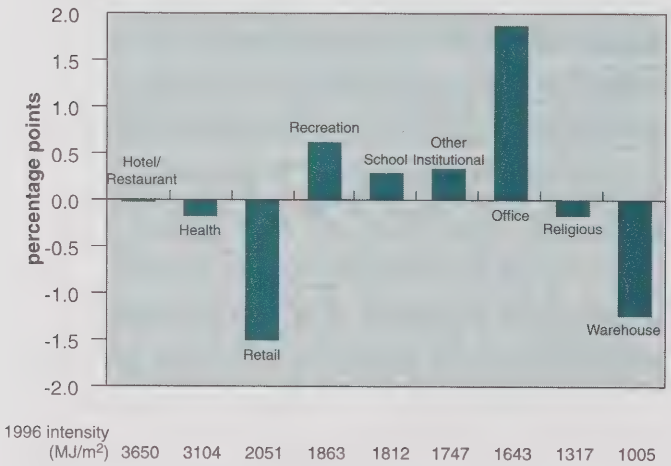
4.1.2 The influence of fluctuations in climatic conditions – the weather effect

The weather effect contributed to a 44 petajoule increase in commercial energy demand, the second largest contributor, after activity, to changes in energy use. Space heating requirements increased since the 1996 winter was colder than the winter of 1990. The heating degree-days in 1996 were 13.7 percent above the 1990 level. A cooler summer in 1996 compared to 1990 — the cooling degree-days were 9.4 percent lower — put a downward pressure on the cooling requirements.

4.1.3 The influence of shifts in the mix of building types – the structure effect

Changes in the mix of activity accounted for only a one-petajoule increase in total commercial energy use over the 1990–1996 period. The structural effect resulted from changes in the distribution of floor area by building type. As shown in Figure 4.6, the net structural effect is the result of many small offsetting shifts in the share of floor space of specific building types.

Figure 4.6 Changes in Commercial Activity Shares by Building Type, 1990–1996 (percentage points)



The increase in the share of floor space for offices (+1.9 percentage points) was offset by the decline in the floor space share for retail buildings (-1.5 percentage points), which have a higher intensity than office buildings. The second largest decline in floor space share (-1.2 percentage points) occurred in the least intensive building type, warehouses.

4.1.4 The influence of variations in the intensity of commercial energy use – the intensity effect

The energy intensity effect was the only factor that reduced the increase in energy use over the 1990–1996 period. Its effect, about 33 petajoules, was significant since energy use would have increased by 15.9 percent if energy intensity had not declined.

This energy intensity effect was evaluated in the context of a low turnover of building stock compared to the 1984–1990 period. As mentioned in section 4.1.1, floor space increased by 11.0 percent between 1990 and 1996, while it increased by 31.9 percent over the 1984–1990 period. If the turnover building stock between 1990 and 1996 had been similar to the 1984–1990 period, the intensity effect would have been much more important since new buildings are more energy-efficient than the average of the existing stock of buildings.

Changes in the energy intensity of a given building type are influenced by, among other factors, changes in i) the energy efficiency of buildings themselves and the equipment they use, ii) institutional factors and iii) the density of occupation of the buildings. These three factors are briefly reviewed below.

Building and Equipment Energy Efficiency[3]

Heating, Ventilating and Air Conditioning (HVAC) Equipment: New heating equipment is more efficient than the average equipment in the building stock with the consequence that new construction and retrofit activities have the effect of reducing the energy intensity of the building stock. HVAC efficiency improvements in new buildings are primarily due to improved control systems and more efficient circulation and ventilation equipment. Boilers and furnaces have reached efficiency levels of about 85 percent. Further efficiency improvements will require the use of more expensive materials to cope with increased flue gas condensation.

Changes in air conditioning equipment have primarily been driven by the shift to non-CFC technologies. In large commercial applications, these systems can be 25 percent more energy-efficient than conventional systems. This efficiency improvement applies primarily to new construction since replacing existing equipment is generally too expensive to justify on the basis of energy savings alone.

Lighting Equipment: Technological changes in lighting equipment have led to energy efficiency gains in new construction and through retrofitting existing facilities. One technological change is the switch from T12 to T8 fluorescent tubes, without loss of lighting quality, resulting in energy savings of 20–25 percent.[4] Another technological change is the switch from conventional ballasts to electronic ballasts,[5] which are 15–40 percent more efficient.[6] Incandescent lights can now often be replaced with compact fluorescent lamps, which are 15–40 percent more efficient.[7]

Office Equipment: This category includes computers, printers, copiers and fax machines. Desktop computers are the largest category by unit sales. Their annual unit sales in 1995 were 107 percent higher than in 1990. Corresponding growth rates for other office equipment are 199 percent for UNIX-based technical workstations, 320 percent for laser printers, 98 percent for fax machines and only 4 percent for photocopiers.

Despite the high growth rate of office equipment, it is hard to assess trends in per unit energy consumption because of two offsetting trends: increased service and efficiency improvements. The first trend is reflected in more powerful computers, larger monitors and more graphics capacity, resulting in higher plug load per unit. The other trend relates to the application of power management technologies that shift equipment to a low-power state when the equipment is not in use. This technology is now standard in desktop computers and is also present in many copiers and some printers.

Institutional factor

Since the early 1990s, there has been an increase in the role of energy service companies (ESCos), which provide energy retrofit services and are responsible for the analysis, design, construction, commissioning and performance monitoring of energy efficiency projects.The ESCo also finances the up-front capital costs of the retrofit project and recovers these costs through the energy savings. Each retrofit project carries a performance guarantee, transferring the financial risk of the project to the ESCo. Investments by the ESCo for a project can range from $50 000 to $10 million.[8] From 1990 to 1995, this industry experienced rapid growth. For example, revenue

3 This subsection is based on CCEEDAC's paper entitled *Commercial Energy Market Trends: 1990-96*, September 1997.

4 Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

5 The ballast is the part of the fluorescent lighting unit that provides the necessary starting voltage and regulates the lamp's current during operation.

6 Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear, T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

7 Ibid.

8 Web site of the Canadian Association of Energy Service Companies.

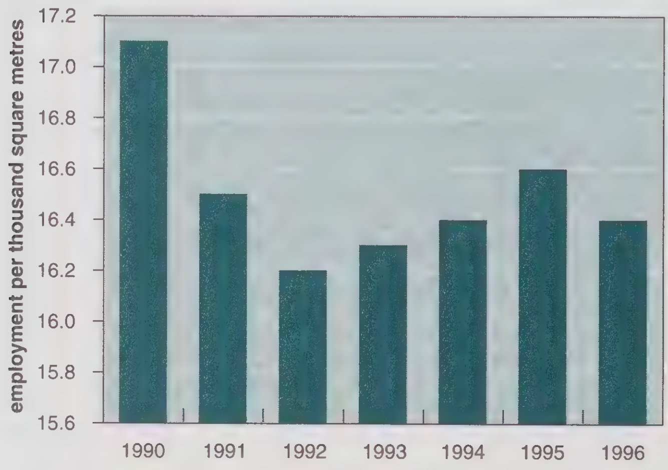
increased at an annual average rate of 47 percent, reaching $278 million in 1995.[9] Energy savings resulting from ESCos' activities increased from 0.9 petajoules in 1994 to 1.7 petajoules 1995.[10]

Occupation Density

Variations in the occupation density of buildings affect energy use and energy intensity. The higher the occupation density of a given building, the higher its energy requirements and energy intensity.

The occupation density indicator, measured as employment in the commercial sector per square metre of floor space, fell by 4.0 percent from 1990 to 1996. Figure 4.7 shows that the occupation density indicator declined in 1991 and 1992, but increased during all subsequent years except in 1996. The trend for this indicator is found in most building types. The variations in the early 1990s are attributed to the combined effect of an oversupply of floor space and a reduction in employment, whereas during the remaining years, a gradual space rationalization and increase in employment took place.

Figure 4.7 Commercial Sector Employment by Floor Space, 1990–1996 (employment per thousands of square metres)

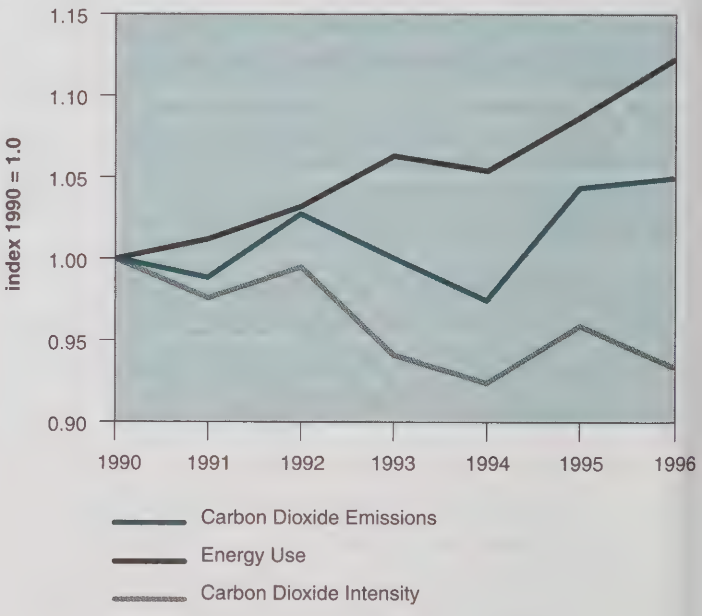


4.2 Trend in the Carbon Dioxide Emissions of Commercial Energy Use

Figure 4.8 presents the trend in carbon dioxide emissions, energy use and carbon dioxide intensity of energy use between 1990 and 1996. Emissions increased 4.9 percent compared to 12.0 percent for energy use. The main reason for this difference is a 6.5 percent decline in the carbon dioxide intensity of energy use. Without the inclusion of emissions associated with electricity use, the carbon dioxide intensity of energy use would have declined by 1.5 percent.

During this period, emissions declined on three occasions, in 1991, 1993 and 1994. The first two downturns can be attributed to a reduction in the carbon dioxide intensity of energy use, while the third one is due to a decrease in both energy use and carbon dioxide intensity. The 1992 and 1995 emission increases are explained by both the growth of energy use and carbon dioxide intensity. The decline of carbon dioxide intensity of energy use in 1996 was the sole factor offsetting the emissions increase of that year.

Figure 4.8 Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1996 (Index 1990 = 1.0)

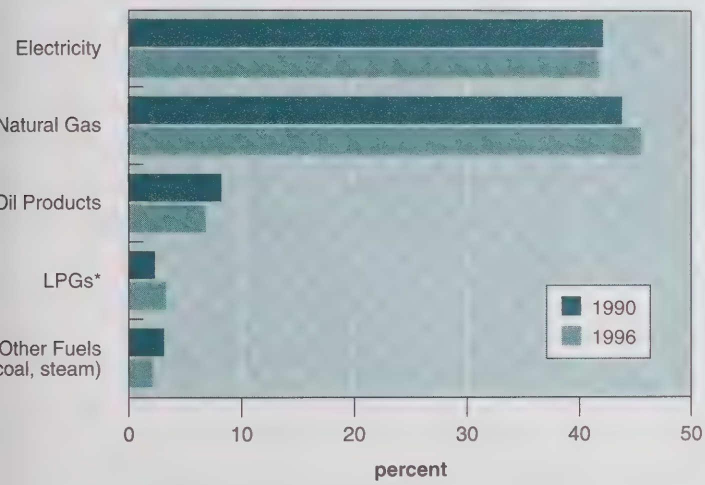


9 Canadian Association of Energy Service Companies, *1995 Annual Review of the Canadian Energy Performance Contracting Industry*, March 31, 1997.

10 Ibid

The 6.5 percent reduction in the carbon dioxide intensity of energy use between 1990 and 1996 can be partly explained by the small changes in fuel end-use shares, which are illustrated in Figure 4.9. A small decline in the share of electricity use (-0.3 percentage point) combined with a significant reduction in the carbon dioxide intensity of electricity (-12.6 percent) put downward pressure on the growth of emissions. During this period, more building owners chose natural gas rather than oil products to meet their water- and space-heating requirements. The main factors underlying this fuel substitution were more competitive natural gas prices and greater regional availability of natural gas.

Figure 4.9 Commercial Energy Fuel Shares, 1990 and 1996 (percent)



* liquefied petroleum gases

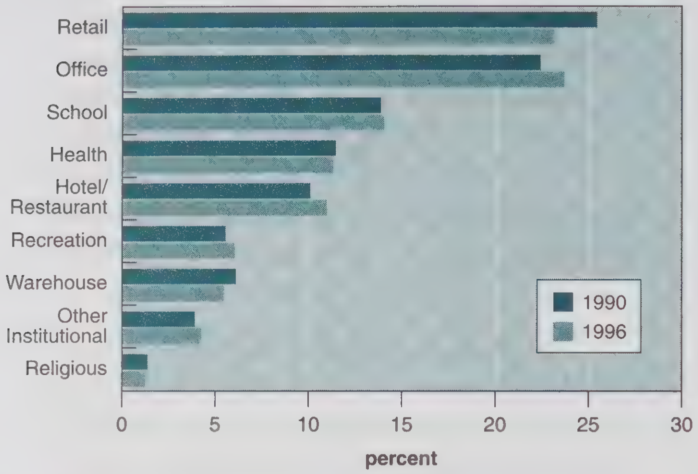
As a result, there was a decrease in the share of oil products (-1.4 percentage points) and an increase in the share of natural gas (+1.7 percentage points), a fuel with a lower carbon content. As in the case of electricity, this fuel substitution caused a reduction in the growth of emissions.

These small changes in fuel shares between 1990 and 1996 mainly result from a small variation in energy prices. Between 1990 and 1996, real energy prices increased by 5.3 percent, while over the 1980–1990 period, they increased by 184 percent. During the earlier period, electricity prices increased at a rate slower than the prices for oil products. As a result, the share of electricity increased by 10.7 percentage points to the detriment of oil products, which can be attributed to the increasing penetration rate of space-cooling systems and office equipment.

The contribution of each building type to the change in total carbon dioxide emissions between 1990 and 1996 is shown in Figure 4.10. Four building types (i.e., office, retail, school and health) represent three-quarters of energy use and a similar share of emissions. These four building types accounted for 53.0 percent of the 2.4-megatonne increase in emissions for the 1990–1996 period.

The main changes in the relative contribution of each building type took place in three areas: office, hotel and restaurant, and retail. The increase (+1.3 percentage points) in office's share of the sector's emissions was mostly due to the growth in natural gas for meeting space-heating requirements for this building type. Thus, natural gas emissions for office buildings increased 22.2 percent. The second largest increase in emissions share after office was hotel and restaurant (+0.9 percentage points), mainly because of the penetration of liquefied petroleum gas in auxiliary equipment (e.g., cooking appliances). The decline in retail buildings' emissions share (-2.2 percentage points) was mostly attributed to a 8.6 percent decrease in electricity emissions for this type of building. The reduction in the carbon dioxide intensity of electricity over the period played an important role in the decline.

Figure 4.10 Commercial Carbon Dioxide Emissions by Building Type, 1990 and 1996 (percent)



4.3 The Data Situation

Aggregate commercial energy use data are published by Statistics Canada under the commercial and other institutional and public administration categories. However, commercial energy use by building type and by end-use is estimated using NRCan's commercial energy end-use model. A key variable for this estimation is floor space, which is used as a proxy for commercial activity. Since there is little reported data, floor space is estimated based on investment flows by structure and asset type and on average construction cost.

In 1997, NRCan contracted Informetrica Ltd. to undertake a thorough review of the current methodology to estimate commercial floor space by building type and by region.[11] As part of this review, floor space estimates were benchmarked against some provincial data from surveys and audits. On the basis of this review, NRCan has increased its estimated Canadian floor space by an average of 4 percent over the historical period. Warehouse and office buildings in Ontario and Alberta accounted for the bulk of the increase.

In mid-1996, NRCan asked ARC Applied Research Consultants and Engineering Interface Ltd. to undertake a detailed study on the feasibility of implementing a data collection strategy for the commercial sector. In their June 1997 report entitled *A Detailed Strategy for Commercial Sector Data Collection in Canada*, the consulting firms recommended that two closely related surveys be undertaken. The first survey will collect energy intensity data at the building type level and the second survey will gather energy intensity at the end-use level for large buildings. The latter survey will rely on equipment databases of building service companies and ESCos. The Canadian Commercial Energy End-Use Data and Analysis Centre[12] also contributed to the development of this strategy.

The proposed surveys will be tested by the end of the summer of 1998. During the second half of 1998, data on floor space, building characteristics and energy-using equipment will be collected. An emphasis will be put on gathering information for new and energy retrofit buildings to assist NRCan in monitoring the impacts of its commercial programs.

11 Informetrica Limited, *1995 Database Update: Historical Estimates of Commercial Floor Space*, December 1997.

12 The centre is funded by Natural Resources Canada and is located at McMaster University, Hamilton, Ontario.

Chapter 5

Industrial Sector

HIGHLIGHTS

- Over the 1990–1996 period, industrial energy use (E) increased by 11.8 percent for a total of 309 petajoules.
- The growth in industrial sector energy use was largely influenced by changes in industrial activity (A), the mix of activity by industry, the structure effect (S), and energy intensity (EI). The impact of these three factors was the following:
  - Industrial sector activity (measured as GDP) increased by 6.5 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 171 petajoules.
  - The change in the mix of activity (structure) towards more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 100 petajoules.
  - There was an increase in energy intensity from 1990 to 1996. Had all other factors remained constant over the period and only industrial energy intensity (EI) changed, industrial sector energy use would have increased by 35 petajoules or 1.4 percent. Aggregate energy intensity (E/A) unadjusted for structure increased 4.9 percent.
- Carbon dioxide emissions (CO_2) resulting from energy use in the industrial sector increased by 5.6 percent from 1990 to 1996, as the impact on emissions of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity (CO_2/E) of industrial energy use decreased by 5.5 percent, as industry moved towards a greater use of fuels with a lower carbon content.

THE ENERGY EFFICIENCY/EMISSIONS BAROMETER—INDUSTRIAL SECTOR

↑ 11.8% E	↑ 6.5% A	↑ 1.4% EI	↑ 3.8% S	↑ 5.6% CO_2	↓ 5.5% CO_2/E

Industrial energy use in 1996 was 2926 petajoules, accounting for 38.3 percent of secondary energy demand in Canada. Industrial energy use-related emissions were 138.8 megatonnes of carbon dioxide, which represented 33.3 percent of emissions from total secondary energy use-related emissions.[1] The industrial sector includes all manufacturing industries, as well as forestry, construction and mining. In this sector, energy is generally used in industrial processes to produce heat and generate steam or as a source of motive power.

Most of this chapter will focus on the six largest energy-consuming industries: pulp & paper, mining, petroleum refining, iron & steel, chemicals, and smelting & refining. As shown in Figure 5.1, together these six industries accounted for less than 30 percent of total industrial activity[2] but used 78 percent of total industrial energy.

1 The definition of industrial energy demand and related carbon dioxide emissions adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. See Appendix D for documentation of the Natural Resources Canada's adjustments.

2 Industrial activity is measured as gross domestic product in 1986 dollars.

Figure 5.1 Distribution of Industrial Energy Use and Activity by Industry, 1996 (percent)

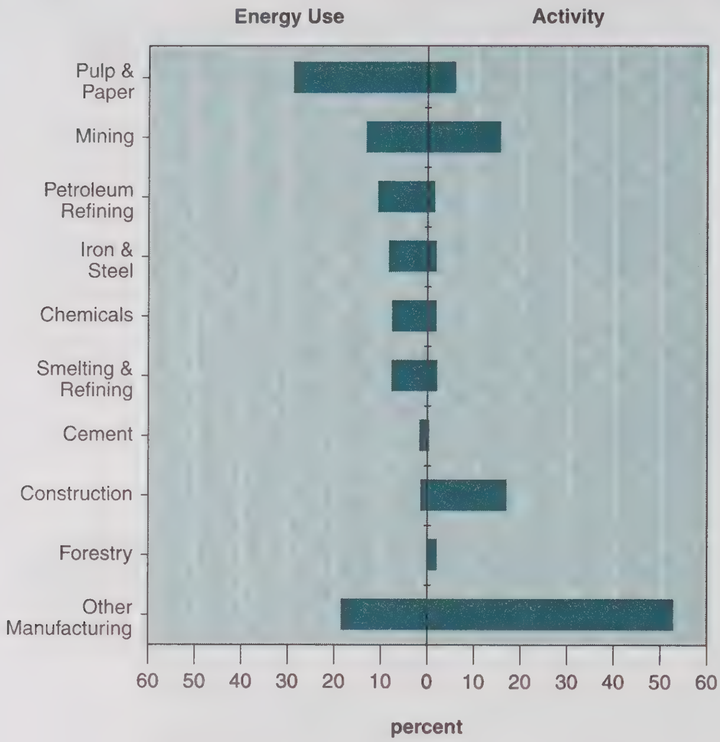
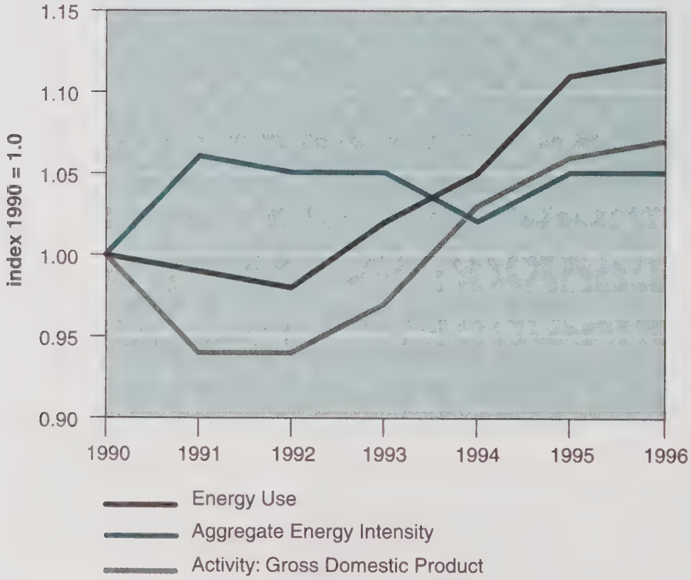


Figure 5.2 shows the trends in total industrial energy use, intensity and activity from 1990 to 1996. Over this period, energy use increased by 11.8 percent while aggregate energy intensity[3] and activity increased by 4.9 percent and 6.5 percent, respectively.

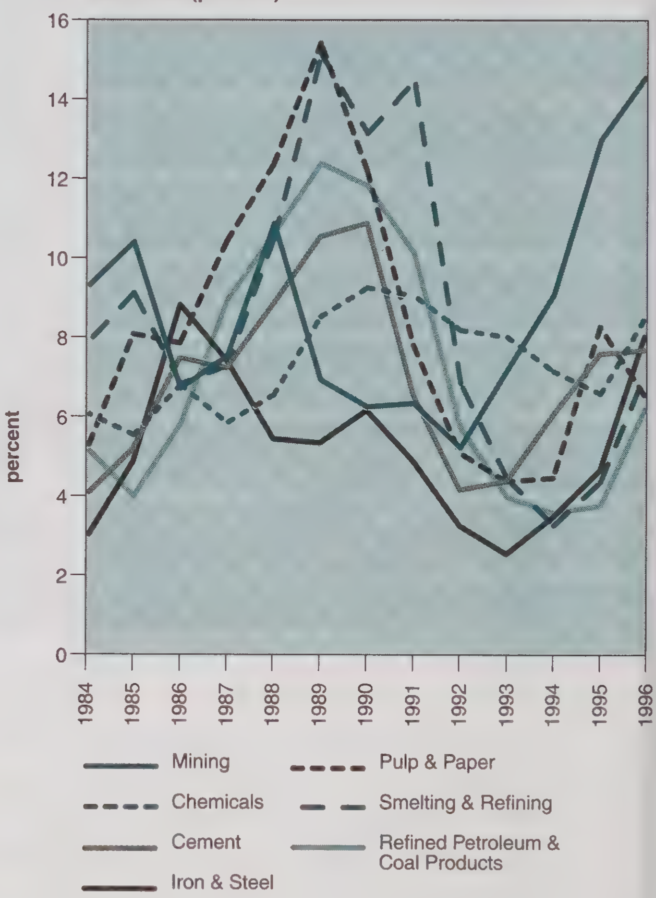
Figure 5.2 Industrial Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)



To better understand the factors underlying the change in energy use that occurred between 1990 and 1996, it is useful to look back at industrial activities in previous years. As industry entered the 1990s, it had just been through six years of significant activity growth.

Figure 5.3 shows that from 1984 to 1996, investments in machinery and equipment relative to the total stock of machinery and equipment increased steadily. This reflects the fact that in a period of growth, industry operates at higher capacity utilization rates and will often add capacity. As new capacity is generally more energy-efficient, industrial intensity decreased by 4.5 percent between 1984 and 1990.

Figure 5.3 Machinery and Equipment Investments as a Share of Total Stock of Machinery and Equipment, 1984–1996 (percent)



3 Industrial sector aggregate energy intensity is defined as industrial energy use divided by gross domestic product.

Between 1990 and 1992 industrial activity declined by 6.1 percent as capacity utilization rates declined and investments in machinery and equipment decreased by about 31 percent. As is typical of periods of decelerating economic activity, energy use declined at a slower pace than activity because of the need to meet fixed energy requirements. As a result, energy intensity increased by 4.7 percent.

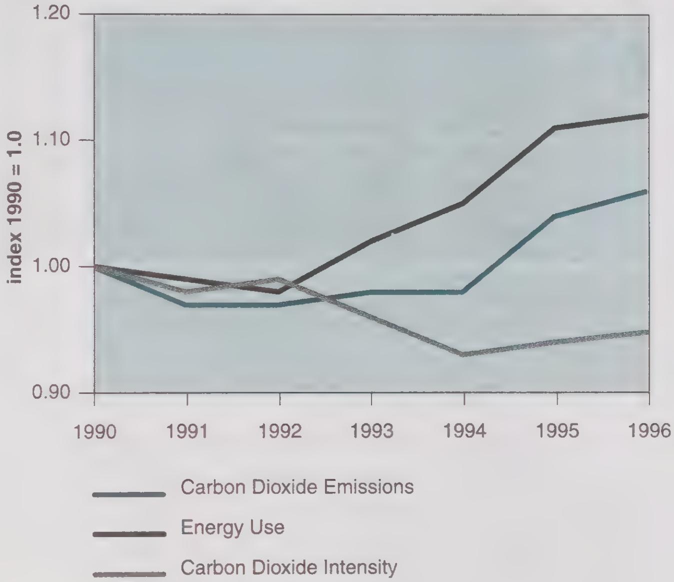
After 1992, the Canadian economy began to recover, and investments in machinery and equipment more than doubled between 1992 and 1996. Figure 5.3 shows that the mining industries are responsible for the bulk of that increase. Mining industries' investments in machinery and equipment as a share of total stock were almost three times higher in 1996 compared to 1992. Industry energy use grew by 13.8 percent over this period. With activity growing at about the same rate (13.5 percent over the period), energy intensity remained flat.

As mentioned earlier, in a period of activity growth and increasing investments, as seen between 1992 and 1996, efficiency gains generally occur at a faster pace. Industrial energy intensity remained flat over the period mainly due to structural changes driven by the mining industries. In fact, the manufacturing industry's energy intensity decreased by 9.0 percent between 1992 and 1996.

Fuel switching can also influence energy intensity. Since 1990, fuel switching in industry occurred, although not as significant as over the 1980s, in part as a response to environmental concerns and in part due to prior considerations.

Figure 5.4 presents the trend in emissions, energy use and the carbon dioxide intensity of energy use from 1990. Total carbon dioxide emissions increased by 5.6 percent since 1990, while carbon dioxide intensity decreased by 5.5 percent. Most of the increase in emissions occurred in 1995 and 1996 as activity grew by an average of 1.6 percent during those years.

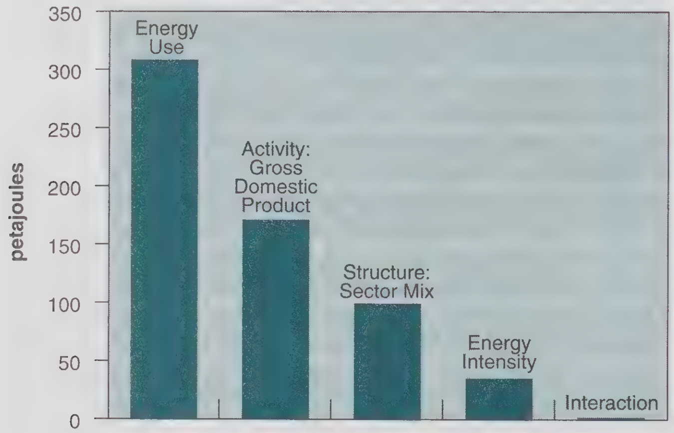
Figure 5.4 Industrial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1996 (index 1990 = 1.0)



5.1 Evolution of Industrial Energy Use and its Major Determinants

Factorization analysis provides an alternative perspective on the change in total industrial energy use. This approach attributes the change in energy use over a given time period to activity, a structure effect (measured as the mix of economic activity among industries) and the energy intensity effect. The results of this analysis for the industrial sector are shown in Figure 5.5.

Figure 5.5 Factors Influencing Growth in Industrial Energy Use, 1990–1996 (petajoules)



*For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

The factorization results show that growth in industrial activity and a change in the mix of industry were responsible for most of the change in energy use between 1990 and 1996. Energy intensity contributed slightly to the increase in industrial energy use.

Figure 5.5 shows that from 1990 to 1996, industrial sector energy use increased by a total of 309 petajoules. The factorization results for the period 1990 to 1996 can be summarized as follows:

- Industrial sector activity increased by 6.5 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 171 petajoules.
- The change in the mix of activity towards more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 100 petajoules.
- There was an increase in energy intensity from 1990 to 1996. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have increased by 35 petajoules.

The energy intensity effect is much smaller than suggested by the 4.9 percent increase in aggregate intensity shown in Figure 5.2. This illustrates the value-added of using the factorization approach for the analysis. In short, it shows that most of the change in aggregate industrial sector energy intensity was due to a shift in activity mix (structure) rather than in industry-specific energy intensities.

The next three subsections describe the reasons underlying changes in activity, activity mix and intensity and their role in explaining changes in industrial energy use. Table 5.1 situates aggregate trends in energy use, activity and intensity with respect to similar trends in the major industries.

Table 5.1
Summary of Trends in Energy Use, Activity and Aggregate Energy Intensity in the Industrial Sector for Major Industries, 1990–1996 (percent change)

	Energy Use	Activity	Aggregate Energy Intensity
Total Industrial	11.8	6.5	4.9
Mining	49.6	24.4	20.2
Pulp & Paper	14.3	5.3	8.6
Iron & Steel	13.1	14.5	-1.2
Smelting & Refining	27.2	38.7	-8.3
Chemicals	11.0	-2.5	13.9
Petroleum Refining	-1.6	7.7	-8.6
Other Manufacturing	-2.8	12.2	-13.4

5.1.1 The influence of growth in industrial activity – the activity effect

Aggregate industrial activity rose by 6.5 percent over the 1990–1996 period. The factorization analysis results attribute as much as 55.3 percent, or 171 petajoules, of the change in energy use over this period to growth in industrial activity.

The sectors that contributed the most to the activity effect were pulp & paper, petroleum refining and the "other manufacturing" industries, which are responsible for 58.6 percent of the industrial sector energy demand and 63.4 percent of the sector's activity. These industries accounted for close to half (107 petajoules) of the increase in energy use due to activity growth, while mining, chemicals and iron & steel contributed to a further 45 petajoules.

Industrial subsectors have expanded at differing rates over the 1990–1996 period, suggesting shifts in activity mix within the sector. Mining, iron & steel and smelting & refining have recorded outstanding growth, while cement has suffered overall declines.

Although domestic demand contributed to industrial production growth in the past six years, the most important source of increased demand for production was in export markets for pulp & paper, mining, petroleum refining, iron & steel, smelting & refining and chemicals. The increased exports resulted from exceptional growth in investments in North America as well as some rebuilding activities after several natural disasters in the United States.

The subsectors responsible for most of the activity growth in other manufacturing were transportation equipment, electrical and electronic products, food and beverages, and rubber and plastic manufacturing. The growth in several of these sectors since 1992 also came from strong machinery and equipment investment spending in Canada and the United States.

5.1.2 The influence of shifts in the distribution of industrial activity – the structure effect

From 1990 to 1996, there was a shift towards more energy-intensive industries. This shift accounts for 100 petajoules of the total 309 petajoule increase in energy use from 1990 to 1996.

Figure 5.6 presents the change in the shares of industrial activity (in percentage terms) accounted for by a selection of industries. At the bottom of the figure, the aggregate energy intensity of each industry in the year 1996 is presented. To the extent that increases in activity shares occur in the most energy-intensive industries, this will have a upward influence on energy use.

Figure 5.6 Changes in Sectoral Shares of Industrial Activity, 1990–1996 (percentage points)

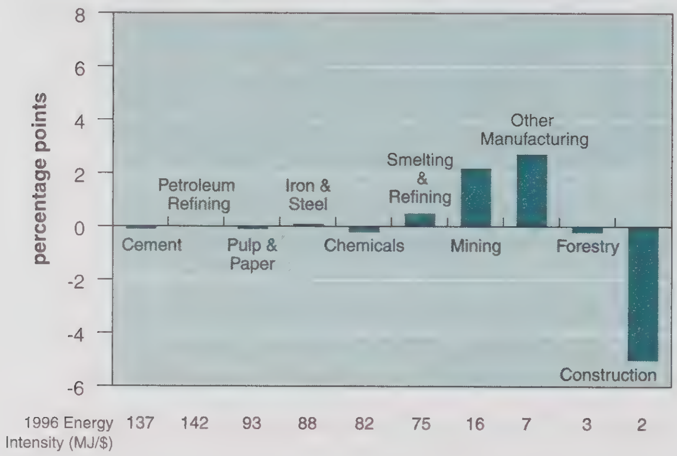


Figure 5.6 also shows that three of the seven most energy-intensive industries increased their activity share from 1990 to 1996 (iron & steel, smelting & refining and mining). Most of the shift occurred in the mining industry, which increased its share by 2.2 percentage points during the period. Production in the mining sector is dominated by the oil and gas industries, which represent 62.1 percent of mining's GDP. This sector grew by 34.1 percent between 1990 and 1996. Together, the seven most energy-intensive industries increased their share of industrial activity by 2.5 percentage points at the expense of construction and forestry.

5.1.3 The influence of variations in the intensity of industrial energy use – the energy intensity effect

The energy intensity effect measures how much energy use would have changed had industrial activity and its structure remained constant over the period and only energy intensity varied. The energy intensity effect for the industrial sector is positive (see Figure 5.5) indicating that, on average, industry-specific energy intensities increased from 1990 to 1996. In fact, if industry-specific energy intensity had not changed from 1990 to 1996, energy use would have been 35 petajoules lower.

The increase in aggregate industrial sector energy intensity is a result of offsetting changes in specific industry groups, which are discussed below. It is important to remember that the energy intensity effect nets out the influence of activity mix but still includes the influence of other effects such as changes in product mix, operating practices, fuel mix and process mix. Therefore, a positive energy intensity effect does not necessarily imply that energy efficiency has deteriorated.

On an industry-by-industry basis, energy intensity declined in the petroleum refining (8.6 percent), smelting & refining (8.3 percent), iron & steel (1.2 percent) and other manufacturing (13.4 percent) industries. Of the aggregate energy intensity effect of 35 petajoules, these four industries contributed a downward influence of 28, 15, 3 and 75 petajoules, respectively.

Conversely, energy intensity increased in the pulp & paper (8.6 percent), mining (20.2 percent), chemicals (13.9 percent) and cement (5.4 percent) industries. Of the aggregate energy intensity effect of 35 petajoules, these four industries contributed an upward influence of 64, 53, 29, and 3 petajoules, respectively.

The increase in energy intensity generally occurred as a result of fuel switching and structural changes such as a shift towards more intensive subsectors within an industry. In the pulp & paper, mining and chemical industries, such factors have offset some of the improvements in energy efficiency.

Fuel switching to oil products in the mining, cement and chemical industries and towards wood wastes and pulping liquor in the pulp & paper industry contributed to an increase in energy intensity in these sectors.

The share of oil products in the mining, cement and chemical industries increased by 4.5, 3.7 and 3.1 percentage points, respectively, mostly to the detriment of electricity and natural gas. The share of wood wastes and pulping liquor in the pulp & paper industry increased by 4.4 percentage points. The burner tip efficiency of oil products, wood wastes and pulping liquor tend to be less than that of natural gas and electricity. As a result, meeting the same end-use requirements using those fuels causes an increase in energy use.

As reported in other parts of this report, an economic measure of activity for the analysis was used because of the requirements of the factorization analysis. The Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC), in collaboration with the Canadian Industry Program for Energy Conservation (CIPEC), has developed energy intensity indicators using physical measures of activity for a number of industries.[4] The rest of this section discusses changes in energy intensity based on our economic measure and the CIEEDAC database. Furthermore, the CIEEDAC database offers greater sectoral industrial disaggregation and allows us, in some cases, to identify movement in production within specific sectors that impact on energy intensity. Table 5.2 summarizes part of this information, and it shows that some of the structural factors that contributed to an increase in sectoral energy intensities include a shift towards more pulp production in the pulp & paper industry, more upstream activities in the mining industry and more production of fertilizers in the chemical sector.

The increase in energy intensity for the pulp & paper sector reflects a shift from the newsprint industry towards the pulp industry. Pulp making requires 64 percent more energy than newsprint per tonne of production.

As shown in Table 5.1, mining GDP increased by 24.4 percent over the period and is dominated by the oil and gas branch, which is included in "other mining" in Table 5.2. The upstream oil and gas mining operations are generally more energy-intensive than the downstream metal and non-metal mining processes. For example, the oilsands upgraders, which increased their production by nearly 55 percent between 1990 and 1996, use about five times more energy per tonne of product than metal and non-metal mining. This structural shift is partly responsible for the sector's increase in energy intensity.

4 Canadian Industrial Energy End-Use Data and Analysis Centre, Simon Fraser University, *Energy Intensity Indicators for Canadian Industry, 1990 –1996*. British Columbia. December 1997.

Table 5.2
Energy Intensity, GDP Share and Change in GDP Share of Additional Selected Subsectors

	Energy Intensity		GDP Share 1996	Change in GDP Share 1990–1996 (percentage points)
	MJ/$	Physical		
Pulp & Paper and Sawmills				
• newsprint	104.0	28.3 GJ/t	30.6	-3.2
• other paper prod.	88.1	12.9 GJ/t	18.9	+1.2
• pulp	300.0	46.5 GJ/t	16.4	+0.6
• sawmills	11.5	25.6 GJ/1000m3	34.2	+1.6
Chemicals				
• organic chemicals	23.1	n.a	50.2	-4.6
• inorganic chemicals	32.4	8.9 GJ/t	27.9	-0.9
• chemical fertilizers	26.5	9.0 GJ/t	21.9	+5.5
Mining				
• metal mines	20.6	0.4 GJ/t	21.6	-4.0
• non-metal mines	48.8	1.4 GJ/t	3.9	-0.4
• other mining*	13.7	n.a	74.4	+4.5
Other Manufacturing				
• transport. equipment	4.1	n.a	19.5	+1.5
• electrical & electronic	1.2	n.a	15.1	+4.0
• food	8.6	n.a	12.7	0.0
• fabricated metal prod.	6.1	n.a	7.8	-0.9
• wood products	10.4	n.a	6.5	-0.1
• printing, publishing	2.4	n.a	5.2	-2.6
• machinery	3.5	n.a	4.6	-0.3
• beverages	5.0	n.a	3.0	-0.2
• plastics	5.9	n.a	2.9	+0.4
• textiles	13.8	n.a	2.4	-0.3
• furniture and fixture	3.8	n.a	2.1	0.0
• rubber	7.2	n.a	1.8	+0.4
• tobacco	1.8	n.a	0.7	-0.1

n.a: Not available.
* Residual of total mining as defined by Statistics Canada. Includes oil and gas industry, coal mines, quarries, gravel pits and contract drilling operations. For this sector, CIEEDAC only collects data for oilsands upgraders (excluding Cold Lakes).

Also contributing to the increase in energy intensity from 1990 to 1996 is a shift in activity from metal mines to non-metal mines. Metal mines production decreased by 16.4 percent over the period and non-metal mines production increased by 8.8 percent mainly due to an increase in potash production. Metal mining processes require about one-fourth the energy of non-metal mining per tonne of production.

Table 5.2 shows that in the chemical industries, there was a shift from production of organic chemicals towards the production of chemical fertilizers. The per unit of GDP energy intensity of chemical fertilizers is about 15 percent higher than the production of organic chemicals. Inorganic chemicals' share of the sector's activity remained stable during the 1990–1996 period.

The effects of fuel switching and structural changes in the pulp & paper, mining, cement and chemicals industries offset some energy efficiency improvements. The CIEEDAC database shows that in the pulp & paper industry, all pulp, paper and paperboard and building board sectors have reduced energy use per tonne of product between 1990 and 1996. Examples of improvements made in those sectors are the recovery and re-use of waste heat energy and steam and the use of high-efficiency motors at Donohue facilities.

The CIEEDAC database also shows that oilsands upgrading has become less energy-intensive during the period (a reduction of 9.5 percent). An example of energy efficiency improvement in this sector is the use of more efficient boilers, the elimination of some pumping requirements, operational changes and the reduction of the water content in bitumen at Suncor Inc.

Considerable improvement was also made in some of the metal and non-metal mines during the 1990–1996 period. For example, various divisions of the Potash Corporation of Saskatchewan Inc. improved their energy efficiency by eliminating unnecessary conveyers and other equipment (vacuum pumps), installing heat exchangers, moving towards more efficient lighting and shutting down some compressors. The Brunswick Mining Division of Noranda reduced its energy consumption per unit of output with waste heat recovery, automatic controls on boilers and other auxiliary equipment computer monitoring.

In the petroleum refining, smelting & refining, iron & steel and other manufacturing industries, which contributed to a reduction in energy intensity between 1990 and 1996, the decline occurred partly as a result of fuel switching towards fuels with higher burner tip efficiency and energy efficiency improvements.

Fuel switching in those sectors include a shift from oil products and coke oven gas (reduction of 13.4 and 7.0 percentage points, respectively) to natural gas (increase of 8.8 percentage points) in the iron & steel industry. The smelting & refining industry reduced its share of coal and oil products by 1.9 and 1.7 percentage points, respectively, and increased its use of electricity by 4.7 percentage points.

Energy intensity reduction in the "other manufacturing" industry reflects a change in the mix within this industry. Between 1990 and 1996, the electrical and electronics industry increased its share of "other manufacturing" GDP by 4.1 percentage points, mostly to the detriment of the printing, publishing and allied industry and the fabricated metal products industry, which decreased their respective share of "other manufacturing" by 2.6 and 0.9 percentage points. The electrical and electronics industry uses only half the energy per dollar of GDP as required by the printing, publishing and allied industry and only 20 percent of the energy used by fabricated metal products.

Energy efficiency improvements in the steel industry include the use of higher efficiency impellers for large pumps, high-efficiency lamps, and the improvement of process controls and automation that allow motor shutdown when not needed at Dofasco Inc. The Lake Erie Steel Company Ltd. improved its energy efficiency by using more natural gas injection and reducing coke consumption, upgrading insulation and installing power demand controls.

5.2 Trend in the Carbon Dioxide Emissions of Industrial Energy Use

The growth in energy use from 1990 to 1996 was the major factor underlying the 5.6 percent increase in emissions from the industrial sector. Had there not been the offsetting impact of carbon dioxide intensity, emissions would have increased at the same rate as energy use.

Figure 5.7 shows the distribution of carbon dioxide emissions by industry in 1990 and 1996. The petroleum refining, iron & steel, mining, pulp & paper and chemical sectors are responsible for 65.4 percent of total industrial emissions in 1996.

Figure 5.7 also reveals that the share of emissions accounted for by the above industries increased by 2.8 percentage points over the period, mainly as a result of the significant growth in emissions from the use of energy in mining. The growth in emissions from mining is directly related to significant growth in energy use in this industry.

Figure 5.7 Industrial Carbon Dioxide Emissions by Industry, 1990 and 1996 (percent)

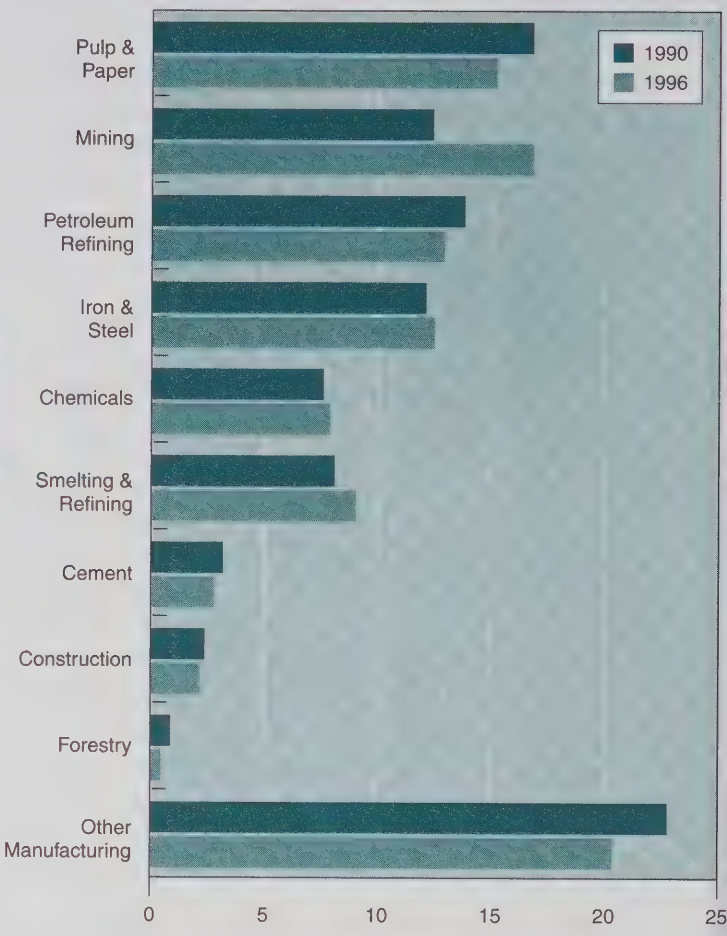


Table 5.3 summarizes the growth in carbon dioxide emissions, energy use and the carbon dioxide intensity of energy use over the past six years for the industrial sector as a whole and for the six largest energy-consuming industries. Carbon dioxide emissions resulting from energy use in the industrial sector increased by 5.6 percent, from 131 megatonnes in 1990 to 139 megatonnes in 1996.

In 1996, electricity-related carbon dioxide emissions represented 26.2 percent of industrial carbon dioxide emissions. If end-use electricity-related emissions had been excluded, the decline in carbon dioxide intensity would have been 3.5 percent rather than 5.5 percent.

Table 5.3
Summary of Trends in Emissions, Energy Use and Carbon Dioxide Intensity of Energy Use for the Six Largest Energy-Consuming Industries (percent change 1990 to 1996)

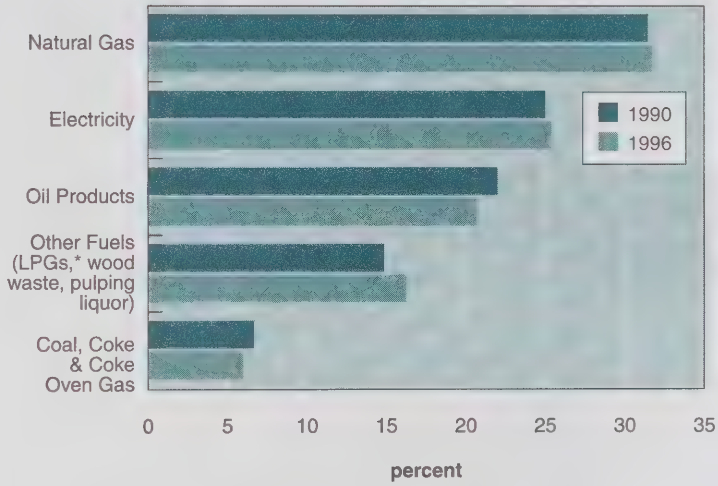
	Emissions	Energy Use	CO_2 Intensity of Energy Use
Total Industrial	5.6%	11.8%	-5.5%
Pulp & Paper	-4.9%	14.3%	-16.8%
Mining	46.0%	49.6%	-2.4%
Petroleum Refining	-0.4%	-1.6%	1.3%
Iron & Steel	7.2%	13.1%	-5.2%
Chemicals	10.5%	11.0%	-0.5%
Smelting & Refining	14.7%	27.2%	-9.8%

Two important observations can be gleaned from the data in Table 5.3. First, both energy use and its carbon intensity had a major influence on carbon dioxide emissions; however, these were offsetting influences, with carbon dioxide intensity mitigating to some extent the rise in emissions resulting from increased energy use. Second, growth rates for carbon dioxide emissions vary widely across industries. Emissions from the mining industry increased by 46.0 percent from 1990 to 1996, while emissions from pulp & paper declined by 4.9 percent.

The 5.5 percent decline in the carbon dioxide intensity of industrial energy use from 1990 to 1996 (see Table 5.2) played a major role in limiting growth in carbon dioxide emissions to 5.6 percent. In the absence of this decline in carbon dioxide intensity, emissions would have increased by 11.7 percent, or an additional 15.4 megatonnes.

The downward trend in carbon dioxide intensity was mainly due to end-use fuel shifting from oil products, and coal and coke oven gas (down 2.1 percentage points) to less carbon dioxide-intensive "other fuels" (up 1.4 percentage points) and electricity (up 0.4 percentage points). These changes in the fuel mix are illustrated in Figure 5.8.

Figure 5.8 Industrial Energy Fuel Shares, 1990 and 1996 (percent)



* liquefied petroleum gases

The major shifts in fuel shares are concentrated in a few industries: mining, pulp & paper and smelting & refining. In mining, the share of natural gas and oil products rose by 5.8 and 4.5 percentage points, respectively, while electricity decreased by 10.6 percentage points. This shift in fuel shares results from above average growth in the upstream and non-metal mining segments of the industry from 1990 to 1996, which rely heavily on natural gas and oil products.

In pulp & paper, the share of natural gas and wood waste & pulping liquor (included in "other fuels") increased by 0.9 and 4.4 percentage points, respectively, while oil products declined by 4.5 percentage points. Pulp & paper increased its share of wood waste and pulping liquor to produce steam and electricity as part of its climate change strategy that focused on reducing fossil fuel consumption and greenhouse gas emissions.

In smelting & refining, the share of electricity increased by 4.7 percentage points, while oil products, coal and natural gas decreased by 1.7, 1.4, and 1.6 percentage points, respectively. The increased use of electricity in smelting & refining reflects the significant growth in aluminum manufacturing, which relies almost solely on electricity. Primary production of aluminum increased by 46.9 percent since the beginning of the 1990s. Aluminum accounts for the bulk of the smelting & refining industry's energy use.

5.3 The Data Situation

The energy use data presented in this report are taken from Statistics Canada's Quarterly Report on Energy Supply and Demand (QRESD). This source is used because it is Canada's official energy supply and demand balance and because it forms the basis for Canada's inventory of greenhouse gas emissions.

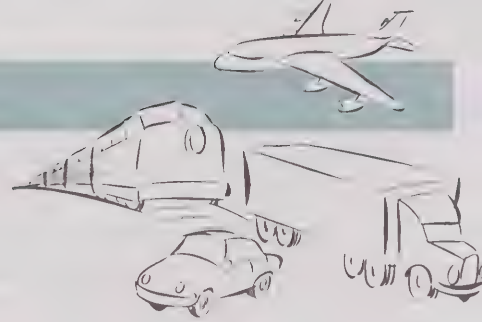
Traditionally, the QRESD data were estimated from a suite of Statistics Canada surveys of energy distributors and end-users. Up to 1993, most of the data were estimated from supply sources. As of 1994, the *Industrial Consumers of Energy* (ICE) survey, one of the sources of end-use data for the QRESD, has been greatly expanded. The 1995 survey included some 2000 respondents, up from a total of 230 respondents in 1993. As a result of expanding the ICE survey, data are now available (starting in 1995) for 24 industry subsectors rather than the previous 10. Environment Canada is now using these data to produce supplementary emissions estimates for these industries.

Natural Resources Canada's understanding of how energy is used in Canadian industry has improved as more information from the ICE survey became available. As a result of better data and discussions with Statistics Canada, we have made some changes to the industrial energy use data. This change better reflected the distinction between the natural gas fuel demand and non-energy feedstock in the chemical industry between 1990 and 1996. A correction was also needed for industrial petroleum coke demand in 1996.

The expanded ICE survey was also used to derive a more disaggregated set of industrial energy use data for the 1990 to 1994 period. CIEEDAC, at Simon Fraser University, has developed a database to track the energy efficiency progress of various industry groups involved in CIPEC. Because CIPEC required disaggregated data going back to 1990 and the expanded ICE is only available since 1994, CIEEDAC had to use a combination of ICE survey data and the *Annual Survey of Manufacturers* data. This database allows us to develop indicators of energy intensity based on a physical measure of activity when appropriate and on an economic measure of output for the entire 1990–1996 period.

For the aggregate level analysis required in this report, GDP is used as a measure of activity in the energy intensity indicators. However, it is recognized that when looking at sector-specific energy efficiency progress, the use of physical output measures is more suitable and the CIEEDAC database is very useful.

The expansion of the ICE survey is a data development initiative funded by NRCan's NEUD. The design of the survey was done in cooperation with CIPEC, Environment Canada and Statistics Canada. The survey is conducted by Statistics Canada.



Transportation Sector

HIGHLIGHTS

- Transportation energy use (E) is composed of a passenger segment, the largest and dominated by light vehicle use, and a freight segment. From 1990 to 1996, passenger transportation energy use increased by 117 petajoules, or 9.8 percent, while freight transportation energy use increased 64 petajoules, or 11.0 percent.
- Several factors caused transportation energy use to change over the 1990 to 1996 period:
  - Energy use increased because activity (A) (measured as passenger-kilometres for passenger transportation and tonne-kilometres for freight transportation) increased — more people, more vehicles, more kilometres. Activity changes were the most significant factor causing energy use to increase from 1990 to 1996. Had activity not changed, passenger and freight transportation energy use would have been 206 petajoules and 86 petajoules lower, respectively, in 1996 than they actually were.
  - The impact of structural (S) change or modal shifts, although small in the passenger segment, was important in the freight segment. Had structure not changed in the passenger and freight segment, 1996 energy use would have been lower by 10 and 88 petajoules, respectively.
  - Aggregate energy intensity (E/A) for the passenger and freight segment decreased by 5.9 and 3.2 percent, respectively; however, energy intensity (EI) adjusted for structure declined 6.6 and 15.4 percent, respectively. Had energy intensity (EI) not declined from 1990 to 1996, energy use would have risen an additional 77 petajoules in the passenger subsector and 91 petajoules in the freight subsector.
- Carbon dioxide emissions (CO_2) increased by 10.2 percent from 1990 to 1996, due to an increase of comparable magnitude in energy use.

PASSENGER TRANSPORTATION

E	A	EI	S	CO_2	CO_2/E
↑ 9.8%	↑ 17.8%	↓ 6.6%	↑ 0.8%	↑ 9.8%	↓ 0.1%

FREIGHT TRANSPORTATION

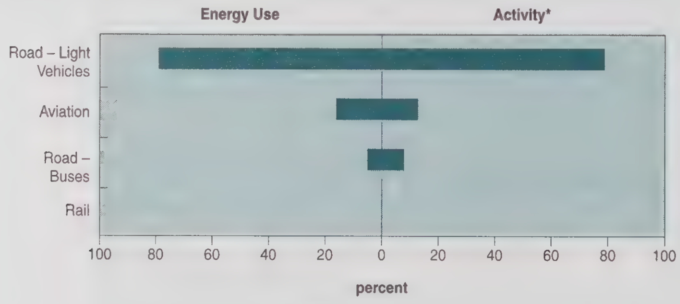
E	A	EI	S	CO_2	CO_2/E
↑ 11.0%	↑ 14.7%	↓ 15.4%	↑ 15.0%	↑ 11.0%	↑ 0.0%

In 1996, the transportation sector accounted for 2029 petajoules, or 26.6 percent, of secondary energy demand in Canada. The resulting carbon dioxide emissions represented 33.8 percent of total secondary energy-related emissions, or 140 megatonnes. Most of these emissions are attributed to road transportation.

The transportation sector includes passenger and freight transportation.[1] The passenger subsector is the largest, accounting for 64.7 percent of transport energy use for road, rail and air passenger activity. The freight subsector accounts for road, rail and marine freight activity.[2]

Light vehicle[3] road passenger transportation is the most significant mode of the passenger subsector, as shown in Figure 6.1. It accounts for 78.9 percent of both energy and activity (passenger-kilometres).[4] Combined with buses, road transport accounts for 83.9 percent of energy and 86.8 percent of passenger-kilometres. The remaining energy and activity are accounted for mainly by the air sector.

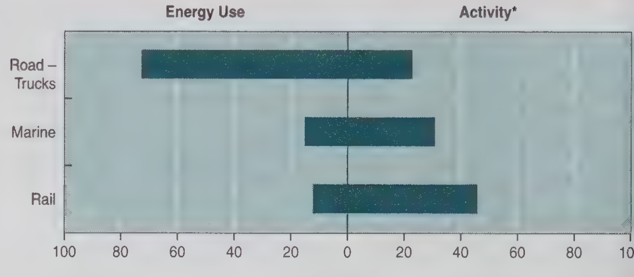
Figure 6.1 Distribution of Passenger Transportation Energy Use and Activity by Mode, 1996 (percent)



* Measured in passenger-kilometres

Figure 6.2 shows that within the freight subsector, trucks account for 72.7 percent of energy use, while marine accounts for 15.5 percent and rail for 11.8 percent. However, because of its competitive advantages in carrying heavy loads on long distances, rail is the most dominant transportation mode with almost 45.6 percent of total freight tonne-kilometres.[5]

Figure 6.2 Distribution of Freight Transportation Energy Use and Activity by Mode, 1996 (percent)



* Measured in tonne-kilometres

Energy use per passenger-kilometre, or aggregate intensity,[6] differs by mode. In the passenger segment, rail and buses are the least energy-intensive modes. On average, light vehicles are more energy-intensive than buses and air is more energy-intensive than road, though over long distances, it can be the most time-efficient mode.

In the freight segment, rail energy intensity is low, as is route flexibility. For freight service providers several factors are considered in the choice of mode, one of which is energy use. While energy and its price are important, it is necessary to recognize the role of other key variables such as time, route flexibility and

1 Also included but not factorized is off-road residential (e.g., lawn mower, outboard) and industrial (e.g., forestry machinery) motor gasoline use.

2 All of marine activity is allocated to freight as no data that would allow for a segmentation of the activity between passenger and freight are available.

3 Light-duty vehicles include small cars (up to 1180 kg, or 2600 lb), large cars (more than 1180 kg), light-duty trucks (up to 4545 kg, or 10 000 lb of gross vehicle weight) and motorcycles. In North America alone there are several different categorization methods used to separate vehicles by size, including the interior car space classification commonly used in the United States. This makes comparisons difficult. For freight, light-duty trucks are less than 4545 kg, medium-sized trucks are 4545 to 15 000 kg (or 33000 lb) and large trucks are greater than 15 000 kg.

4 There is an availability and quality dimension to passenger transport activity data. On the former, passenger transport activity (passenger-kilometres) does not include the non-commercial airline segment, as there is no time series data. On the quality issue, passenger-kilometre numbers exist for rail and air, while numbers for road light vehicles and buses are calculated on the basis of other data. Where estimates are used, an effort is made to substantiate the estimated trends with survey data.

5 Freight activity data, defined as tonne-kilometres, are also partial as they cover all rail, all of marine and a portion of trucks. Statistics Canada's road freight activity is limited to large commercial trucking since it includes only Canadian intercity activity by Canadian-domiciled, for-hire trucking companies with an annual revenue of $1 million. Activity includes the Canadian portion of international freight, both export destined and import freight. In this report, all Statistics Canada reported activity, although incomplete, is used to define heavy truck (over 15 000 kg of gross vehicle weight) activity. Light-duty and medium truck activity, which pertain mainly to service trucking, are assigned fixed weight to kilometre ratio as a proxy for activity. Marine freight data cover the domestic portion of activity as reported by Transport Canada.

6 In this chapter, aggregate energy intensity is defined simply as the ratio of energy used over distance travelled. In the case of passenger transport, the ratio is energy per passenger-kilometre. For freight, it is energy per tonne-kilometre.

convenience, in fuel and mode choices. From the consumers' point of view, their purchase of freight service is mainly based on factors such as price, time constraints, reliability and convenience.

This chapter focuses on the factors that increased transportation energy use from 1990 to 1996. First, passenger transport is addressed. In this subsector, the focus is on road and, within it, light vehicles. This is followed by a separate section on freight. The chapter ends with a section on carbon dioxide emissions related to transportation energy use and an overview of the data situation in the sector.

6.1 Evolution of Passenger Transportation Energy Use and its Major Determinants

Passenger transport energy use[7] increased 117 petajoules, or 9.8 percent, from 1197 petajoules in 1990 to 1314 petajoules in 1996. Most of this increase was in the road segment, where the increase was 95 petajoules, or 9.4 percent. Total passenger activity increased about 94 billion passenger-kilometres, or 17.8 percent, between 1990 and 1996, of which the road segment accounted for 81 billion. Road segment activity increased 17.7 percent between 1990 and 1996. Within the road market, cars account for 82.2 percent of light vehicle road passenger-kilometres, of which small cars account for 51.1 percent. Light trucks, which include minivans and sport utility vehicles, account for only 17.8 percent of light vehicle road passenger-kilometres but are the fastest growing vehicle type. The share of activity accounted for by light trucks within the light vehicle segment increased by 3.2 percentage points at the expense of cars.

Figure 6.3 shows that the growth in passenger transport activity outpaced the change in energy use from 1990 to 1996. As a result, aggregate passenger transport energy use intensity, measured as energy per passenger-kilometre, has fallen over the period 1990–1996. This aggregate intensity encompasses the effects of a wide range of factors, including fuel switching, technological improvements, modal shifts and behavioural change. Later in this chapter, the factorization method provides a measure of net intensity of the influence of modal and vehicles mix shifts.

Figure 6.3 Passenger Transportation Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990=1.0)

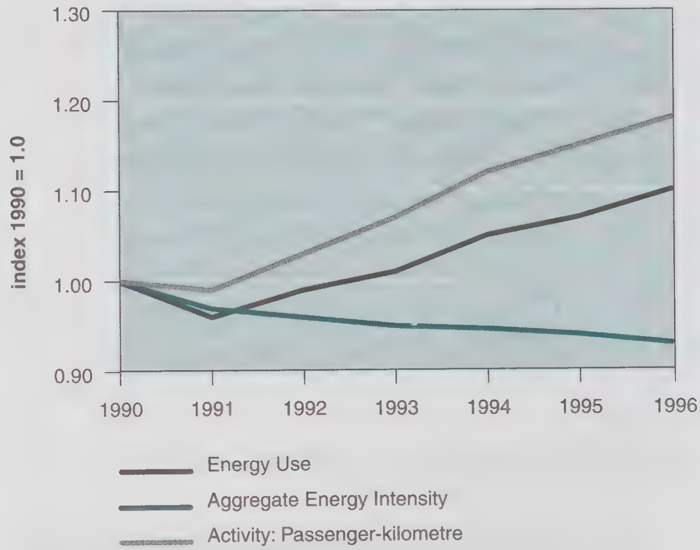
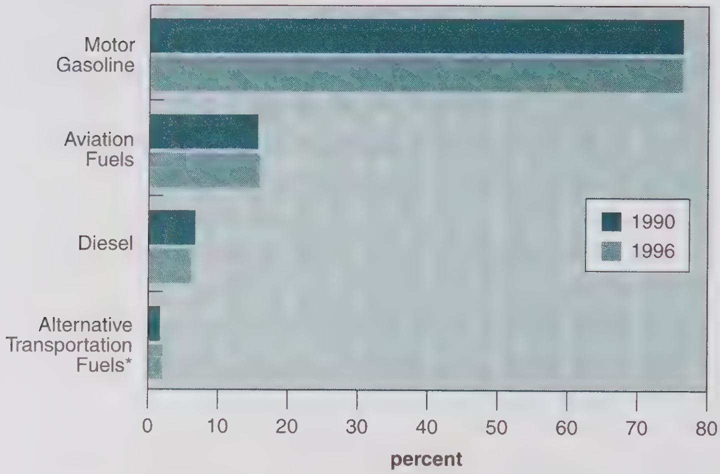


Figure 6.4 shows that changes in passenger transportation fuel shares favoured aviation and alternative transportation fuels, which increased their market share by less than half a percentage point between 1990 and 1996. These changes occurred at the expense of motor gasoline and diesel fuels whose shares decreased by 0.1 and 0.6 percentage points, respectively.

7 The total change in passenger transport energy use from 1990 to 1996 is 117 petajoules. However, in the section in which the impact of factors affecting energy use changes are isolated, non-commercial airlines are excluded from the analysis. As non-commercial airline energy use declined from 1990 to 1996, the change in total passenger energy use being explained is 125 petajoules rather than 117.

Figure 6.4 Passenger Transportation Fuel Shares, 1990 and 1996 (percent)



* includes propane, natural gas and electricity

The distribution of passenger transportation energy use by mode changed marginally from 1990 through 1996. Figure 6.5 shows a modest shift towards road light vehicles and aviation at the expense of road buses and rail. Energy use shares of road light vehicles and aviation increased from 78.0 percent to 79.1 percent and 15.5 percent to 15.8 percent, respectively, while bus and rail shares declined from 6.4 percent to 5.0 percent and 0.4 percent to 0.2 percent.

Figure 6.5 Passenger Transportation Energy Mode Shares, 1990 and 1996 (percent)

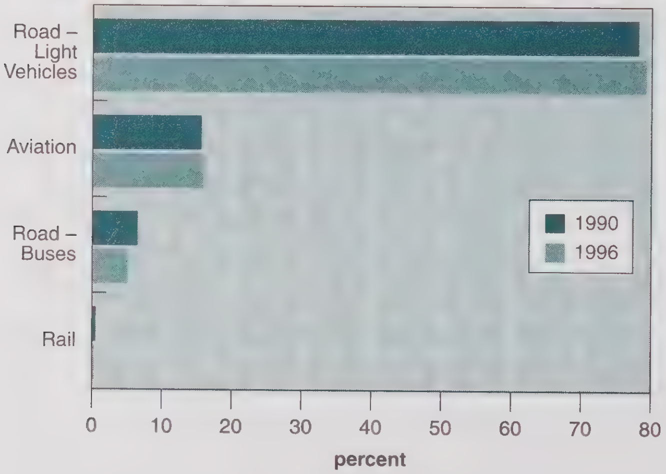
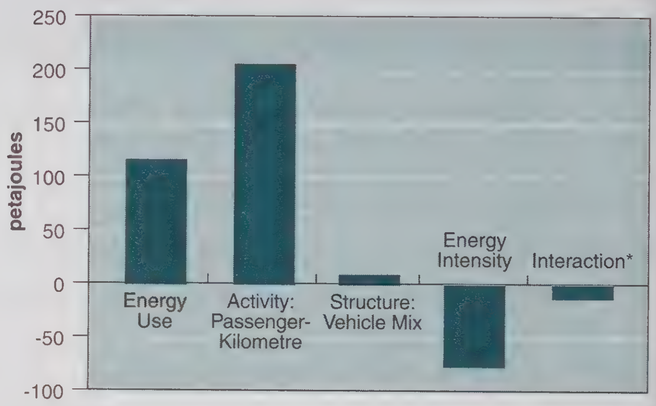


Figure 6.6 shows the impact of the key factors that have contributed to the 117 petajoule increase in passenger transport energy use between 1990 and 1996.[8] The factorization method used separates the influence of the impact of activity (total passenger-kilometres), structural shifts (between mode types) and modal energy intensity on the change in passenger transport energy use. Over the period, passenger-kilometres increased 17.8 percent to 619 billion passenger-kilometres. Had only activity changed, passenger transportation energy use would have increased by 206 petajoules, rather than the observed increase of 117 petajoules.

Figure 6.6 Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1996 (petajoules)



* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

Energy intensity was an important offsetting factor to activity growth on changes in energy use. Had energy intensity not declined, passenger transportation energy use in 1996 would have been 77 petajoules higher than it was. Most of the energy intensity decline occurred in the light vehicle market segment.

8 The change in energy use that is shown in Figure 6.6 is the actual change for this sector, which is 117 petajoules. However, the sum of the factor impacts (i.e., activity, structure, intensity and interaction effects) adds up to 126 petajoules because the factorization analysis excludes the non-commercial airline segment (i.e., commercial/institutional and public administration). The non-commercial airline segment used 39 petajoules in 1990 and 31 petajoules in 1996. An additional, but less significant, reason for the difference is the use of a motor gasoline equivalency value for alternative transportation fuels.

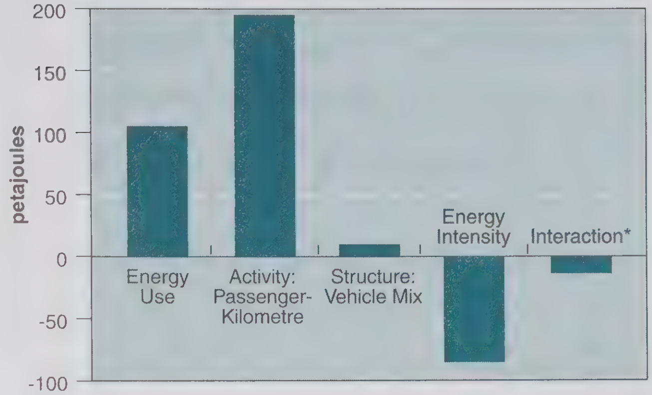
Structural shifts had little influence over the change in total passenger energy use. A small shift in passenger transportation modes, mostly from road buses to road light vehicles and aviation, modestly increased passenger transport energy use from 1990 to 1996. Since road light vehicles and aviation tend to be more energy-intensive on a per passenger-kilometre basis than road buses, this modal shift contributed to an increase in energy demand of 10 petajoules.

These factorial indicators show that improvements in energy intensity was the principal factor offsetting the influence of increased activity on the change in passenger transport energy use between 1990 and 1996. These factors are discussed in more detail in the following four subsections. The discussion of the road segment provides a separate decomposition of factors for light vehicles (cars and light trucks) and buses. More attention is devoted to light vehicles since these account for most passenger transportation energy use—78.9 percent in 1996. The subsections on air and rail describe their respective contributions to the change in total passenger energy use.

6.1.1 Light Vehicles

Figure 6.7 shows the influence of the principal factors contributing to the 106 petajoule increase in light vehicle road transportation energy use from 1990 to 1996.[9]

Figure 6.7 Factors Influencing Growth in Light Vehicle Passenger Transportation Energy Use, 1990–1996 (petajoules)



* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

Again, the most important factors are activity and energy intensity. From 1990 to 1996, light vehicle activity, defined as passenger-kilometres, increased an estimated 20.9 percent. Had only activity changed over this period and other factors remained at their 1990 levels, energy use would have increased by 195 petajoules instead of the actual increase of 106 petajoules.

A number of factors help to explain the increase in road passenger transportation activity. Over the period, population grew by over 2 million, the stock of cars and light trucks used for passenger movement is estimated to have increased by over 650 000 vehicles, and the average distance travelled per year by light-duty vehicles is estimated to have increased by 17.4 percent to 18 384 km in 1996.

Changes in average distance travelled per year may reflect changes in the stock composition of light-duty vehicles, consumers' reaction to changes in economic conditions and the socio-demographic environment.

9 The change in total energy use presented in Figure 6.7 differs slightly from the actual change in light vehicle passenger transportation energy use because the factorization of energy use for this subsector uses a motor gasoline energy equivalency value for alternative transportation fuels.

In terms of stock composition, light trucks and large cars tend, on average, to be driven more than small cars. An increased proportion of light trucks in the stock can have an upward influence on the average distance travelled. Over the period, the share of new light trucks and large cars as a proportion of new vehicles sold has increased.

- From 1990 to 1996, the share of light-duty vehicle stock held by light trucks increased 2 percentage points at the expense of cars. The growing popularity of minivans and sport utility vehicles supports this trend.

Another factor that influences modal choice and activity is the change in the relative cost of transportation by mode. The cost of driving a private vehicle has fallen relative to the cost of urban and intercity bus transport. Some of the cost indicators that are consistent with driving more include:

- The average cost of public transit has risen 41 percent since 1990.[10]
- Total variable driving costs are up about 11.6 percent compared to 1990 while new light vehicle purchase prices are up about 25.0 percent.[11] The average cost for parking has increased 32.3 percent, and the real price of gasoline decreased by about 4.3 percent since 1990. Overall, the ratio of variable to total driving costs has declined 13.7 percent since 1990.

Real disposable income per capita declined almost 6 percent between 1990 and 1996, which typically has a dampening influence on passenger-kilometre activity. However, this decline combined with a high exchange rate could also induce consumers to substitute cheaper domestic road vacations for air or rail travel.

Changes to the socio-demographic environment can also have an influence on vehicle use. For example; urban sprawl, which may result in longer travel distance to work, a growing proportion of two income families and individuals with two or more jobs can change driving needs and distance travelled.

Structural shifts in the mix of activity between small cars, large cars and light trucks also had an upward influence on energy use. Over the period, the activity of light-duty trucks has increased more than small and large cars. Between 1990 and 1996, passenger-kilometre activity for small cars increased 20.3 percent and that of large cars increased 10.6 percent while light truck activity increased 47.3 percent. The aggregate impact of a modal shift to light trucks relative to small and large cars, with all other factors remaining the same, was to increase light-duty vehicle energy demand by 10 petajoules.

One factor mitigating the increase in light vehicle transport energy use was the improvement in energy intensity. Had energy intensity not changed from its 1990 level, energy use would have been 85 petajoules higher than it was in 1990. There are two principal reasons for this intensity improvement. First, new car fuel economy, defined as litres per 100 kilometres, has declined over the years. Figure 6.8 shows average new and average vehicle stock fuel economy since 1978. The most rapid fuel economy improvements occurred between the mid-1970s and through the early 1980s, in large part because newer vehicles weighed less and had less power compared to their 1970s counterparts.[12] In the 1990s, the trend has been to increase power and to a lesser extent size, which has slowed new car fuel economy improvements.[13]

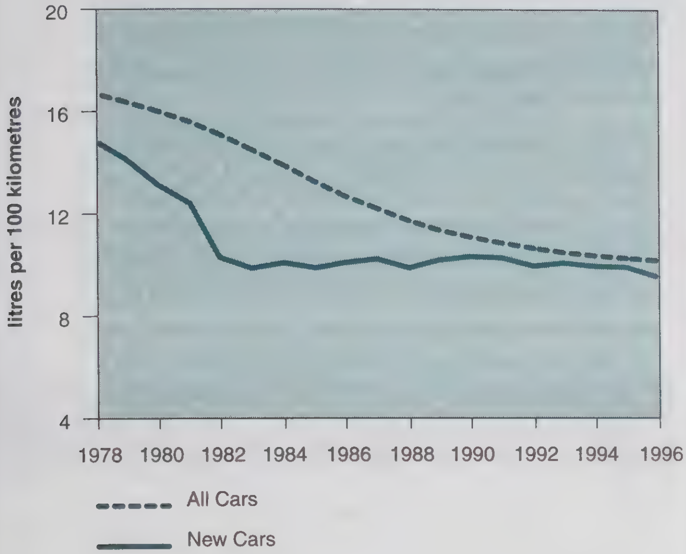
10 The causal factors that encourage individuals to substitute private vehicle travel for public transportation are complex since they include both explicit and implicit costs, such as the value of time in commuting.

11 Variable costs include fuel, tires and maintenance, and fixed costs include depreciation, insurance and licence fees. Cost data are from the Canadian Automobile Association (CAA) annual publication *Driving Costs*.

12 Average horsepower ratings for new cars declined from the mid-1970s through to the early 1980s when they levelled out. Horsepower ratings increased marginally over the 1980s and increased thereafter. At the same time, engine size, as measured by displacement, declined from the mid-1970s through to 1988. Engine displacement has been inching upward since then. In spite of this trend, engines have typically become more efficient in that the horsepower to engine size ratio has increased almost every year since 1976. Technological improvements that have improved fuel economy include improvements to the drivetrain (increase number of gears, electronic overdrive, lubricants that reduce drivetrain friction) and engine (electronic controls and better valve controls) as well as improved aerodynamics (reduced wind resistance and tires with less road resistance).

13 While fuel economy, measured as L/100 km, has not improved much in the 1990s, fuel efficiency may be better. The indicator L/100 km is a measure of fuel intensity rather than fuel efficiency. Some additional transport indicators are required to get closer to measuring fuel efficiency. Some of these are suggested in the sidebar titled "Transport Indicators."

Figure 6.8 Trends in on-road Car Fuel Economy, 1978–1996 (litres per 100 kilometres)



The second factor affecting overall intensity is stock turnover, as new vehicle sales provide for stock growth and replacement of older vehicles, which have lower fuel economy (using more fuel per 100 kilometres). Changes to the fuel economy of the stock are driven by the fuel economy of new vehicle sales and the fuel economy of discarded vehicles. Table 6.1 provides a summary of the vehicle stock by vintage and fuel economy and typical vehicle characteristics. New vehicles have changed and their proportion in the stock has evolved between 1990 and 1996. In 1996, 4 percent of the car stock was 1970s vintage compared to 19 percent in 1990. Over the same six-year period, 1990 vintage vehicles have grown from 6 to 45 percent of the stock.

Transport Indicators

The Need for Additional Indicators to Understand Trends:

The traditional measure of transport fuel economy is L/100 km. This is a good aggregate indicator of intensity. However, a measure of efficiency typically assumes similar service characteristics over time. In the case of transport, safety, comfort and vehicle performance characteristics have changed considerably. As a result, alternative indicators may need to be developed that account for the changing nature of transport today compared to yesterday. Some of these alternative indicators of fuel economy show that fuel economy has not been stagnant since the mid-1980s. For example, both L/100 km/kg and L/100 km/hp show different declines than L/100 km over the same period. Additional transport indicators are needed to better understand changes in fuel economy and fuel efficiency over time.

Table 6.1
Age Distribution and Characterization of the Car Stock, 1990 and 1996[a]

Year/Vintage	1970s Vintage (and older)	1980s Vintage	1990s Vintage
Stock Share in 1990 (percent)	19.0	75.0	6.0
Stock Share in 1996 (percent)	4.0	51.0	45.0
Fuel Economy[b] (L/100 km)	15.3	10.2	10.1
Characterization[c]			
Weight	2 tonnes	1.5 tonnes	1.6 tonnes
Horsepower	135 hp	100 hp	140 hp

(a) Data on vehicle stock are based upon vehicle registration data, which have been provided by Desrosiers Automotive Research Inc. For both 1990 and 1996, the estimates were made as of July 1.

(b) Fuel economy is a stock-weighted estimate for stock in each period. Actual on road fuel use is typically higher. New vehicle fuel economy ratings for each model year are sales-weighted averages based on Transport Canada's Fuel Consumption Rating calculated from Vehicle Fuel Economy and Emissions system data or the annual Automotive News Market Data Book.

(c) The characterization indicated here is intended to highlight the most important features of vehicle design that impact on fuel economy.

Over time, fuel economy improvement has been diminishing and so has the difference between average stock and new vehicle efficiency.

6.1.2 Bus[14]

Total bus energy use decreased 8 petajoules between 1990 and 1996. Intercity bus energy use fell by 3 petajoules, while urban bus energy use fell by 5 petajoules and school bus energy use remained stable. In 1996, bus transportation accounted for 5 percent of passenger energy use and for 7.7 percent of passenger transportation activity. Urban buses are the most important segment, accounting for 42 petajoules, while school buses account for 12 petajoules and intercity buses for 11 petajoules.

Bus activity decreased from an estimated 51.6 billion passenger-kilometres in 1990 to 47.7 billion in 1996. Intercity bus activity declined from 16.3 to 15.6 billion passenger-kilometres. Urban passenger-kilometres decreased from 22.4 to 19.7 billion, and school bus activity fell from 12.9 to 12.3 billion passenger-kilometres.

If only activity in the bus segment and its mix had changed, energy use would have decreased 6 petajoules.[15] Had only intensity changed in that segment, energy use would have decreased 1 petajoule.

6.1.3 Aviation[16]

Aviation accounts for 13.4 percent of passenger energy use[17] and 12.9 percent of passenger-kilometres. Between 1990 and 1996, energy use increased 20 percent to 176 petajoules, while passenger-kilometres increased 19.9 percent to 80 billion passenger-kilometres. Changes in activity alone would have increased energy use 29 petajoules. Energy intensity improvements would have produced a 0.7 petajoule increase in energy use had all other factors remained unchanged. No significant gains were achieved in the ratio of passenger-seating utilization to capacity.

6.1.4 Rail

Passenger rail transport accounts for less than 0.2 percent of passenger energy use and over 0.2 percent of passenger-kilometres. Between 1990 and 1996, energy use declined more than 50 percent to 2 petajoules while passenger-kilometres declined 26.5 percent. Had only activity changed, energy use would have declined by 1 petajoule.

Had only intensity changed, energy use would have declined just less than 2 petajoules. Energy intensity improvements were realized as the passenger train system was rationalized, with low-capacity and low-profit lines being eliminated.

6.2 Evolution of Freight Transportation Energy Use and its Major Determinants

In 1996, freight transport energy use was 650 petajoules, which accounted for 8.5 percent of total secondary energy use. Freight energy use-related emissions were 46 megatonnes of carbon dioxide, which represented about 11.0 percent of secondary energy use-related emissions.

14 Data development undertaken over the last year has allowed for a better definition of bus passenger transportation. Bus stock now includes three vehicle types: school, urban and intercity buses.

15 This is the combined effect of activity and structure, which is sometimes referred to as weighted activity.

16 This subsection and the next describe their respective contributions to the change in total passenger energy use.

17 The factorization analysis excludes the non-commercial airline segment (i.e., commercial/institutional and public administration). The aviation sector accounts for 15.8 percent of passenger energy use when non-commercial airline aviation is included.

The freight sector includes activity[18] related to movement of goods by trucks, rail and marine. Truck activity includes service trucking, which relates mainly to the light and medium truck segment.[19]

Freight trucking accounts for the largest share of freight energy use (72.7 percent) followed by marine and rail (15.5 percent and 11.8 percent, respectively). Activity distribution, defined as tonne-kilometres, is significantly different than energy use as trucks account for only 23.5 percent of total freight activity,[20] while rail and marine account for 45.6 and 30.9 percent, respectively.

Figure 6.9 shows the change in freight transport energy use, activity and aggregate intensity[21] from 1990 to 1996. Freight transportation energy use increased 64 petajoules, or 11.0 percent. Over the period, freight activity, measured in tonne-kilometres, increased 14.7 percent.

Figure 6.9 Freight Transportation Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

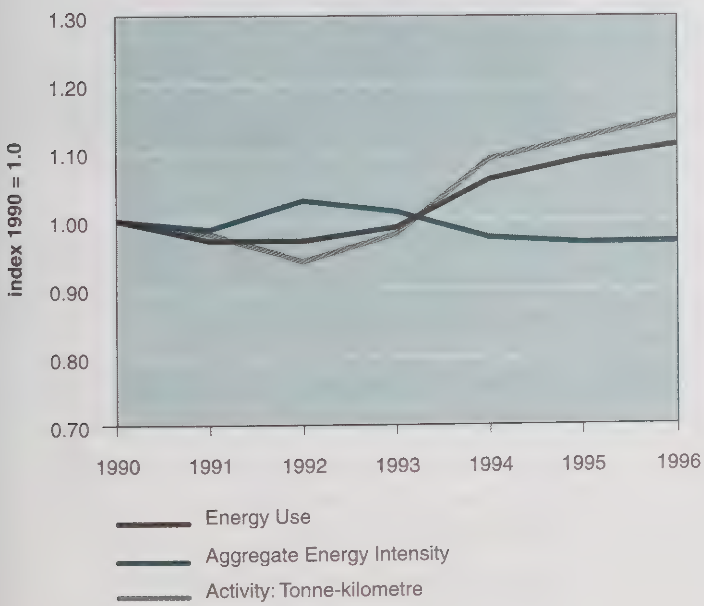
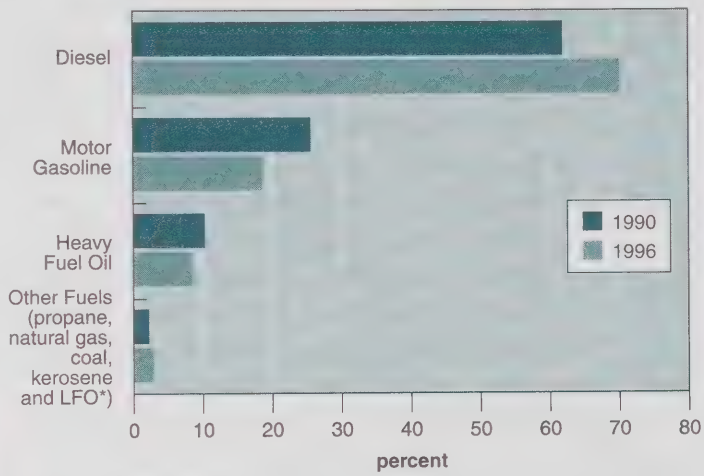


Figure 6.10 shows freight transport fuel share changes between 1990 and 1996. In 1996, diesel fuel accounted for 70.1 percent of freight transport energy use. Its share has risen 8.1 percentage points between 1990 and 1996. At the same time, use of "other fuels" has increased by close to one percentage point to 19 petajoules in 1996. Motor gasoline's share of freight energy use declined 7 percentage points to 18.6 percent, while heavy fuel oil's share declined 2 percentage points to 8.4 percent.

Figure 6.10 Freight Transportation Energy Fuel Shares, 1990 and 1996 (percent)



* light fuel oil

18 The activity data (tonne-kilometres) underlying the analysis presented in this section are incomplete. They cover all rail, all marine and a portion of trucks. As a result, the coverage of energy is broader than that of tonne-kilometres, although it was improved over last year. The reader should use the freight transportation sector analysis with care.

19 Service trucking includes commercial activity such as store delivery, domestic repair services, public utilities repair and service activities and road maintenance.

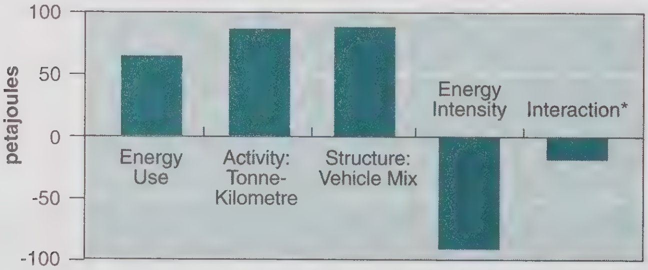
20 The treatment of truck-related freight activity has changed since the last publication, therefore, both current and historical measures of tonne-kilometres are different here than they were in previous versions of this document. In this report, Statistics Canada – reported trucking activity is used to determine large truck activity. Light-duty and medium trucks are assigned fixed weight to kilometre ratios as a proxy for activity.

21 There are differences between the aggregate freight energy intensity presented in Figure 6.9 and the factorial intensity presented in Figure 6.11. The aggregate intensity of freight transport is defined as the ratio of freight energy use over tonne-kilometres, which reflect the impact of the mode mix on freight energy use. The factorial intensity is defined as the impact of the mode-specific energy intensities.

The increased share of diesel fuel use was driven by the growth in the share of large trucks, all of which are diesel fuelled, and a larger share of medium and light trucks using diesel. Large trucks, which represent 42.7 percent of total freight energy use and 19.6 percent of freight tonne-kilometre activity, accounted for most of the diesel fuel use increase over the period.[22] Gasoline is mostly used by light-duty trucks. Over the period, most fuel switching occurred in the medium truck category, where gasoline's share decreased from 69.8 to 45.1 percent, while diesel's share increased from 30.2 to 54.9 percent.

Figure 6.11 presents the factors influencing the growth in freight transportation energy use. Had all factors except activity remained at their 1990 levels, freight transport energy use would have increased by 86 petajoules. Structural shifts towards trucks at the expense of marine increased energy use. Structural shifts alone would have caused an increase of 88 petajoules in freight transport energy use between 1990 and 1996. If energy intensity had not declined, total freight transport energy use would have been an additional 91 petajoules higher in 1996.

Figure 6.11 Factors Influencing Growth in Freight Transportation Energy Use, 1990–1996 (petajoules)



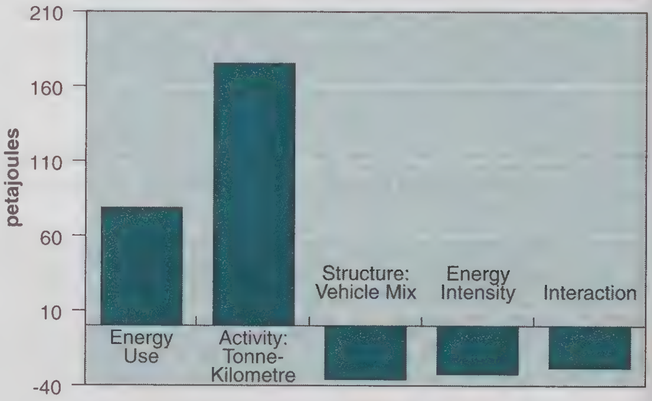
* For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix B.

The largest contributor to total freight activity growth was road freight activity (tonne-kilometres), which increased by 44.2 percent, followed by rail and marine activity, which increased by 12.9 and 1.2 percent, respectively, from 1990 to 1996.

6.2.1 Road

Figure 6.12 shows the factorial indicators contributing to the 79 petajoule increase in road freight transportation energy use between 1990 and 1996. The most important factor is activity, which was partly offset by changes in vehicle mix and improved energy intensity.

Figure 6.12 Factors Influencing Growth in Road Freight Transportation Energy Use, 1990–1996 (petajoules)



There were two main legislative changes that affected freight trucking in Canada over the 1990-1996 period. These were:

1) The 1987 *National Vehicle Transportation Act* (NTA) was amended in 1993. Its amendment further reduced entry barriers to applicants potentially providing for more activity. The regulation now focuses more on safety standards for equipment and operating practices which can lead to fuel economy improvements.

22 This analysis uses three truck size categories. Small trucks are those with a gross vehicle weight (GVW) of 4545 kilograms or less, medium trucks have a GVW from 4545 to 15 000 kilograms and heavy trucks have a GVW greater than 15 000 kilograms.

2) With the opening of the North American trucking market through policies such as the *Free Trade Agreement* (FTA), the Canadian trucking industry has benefited from strong growth in export traffic over the 1990 to 1996 period.

Average annual distance travelled increased 36.8 percent for medium trucks and 35.3 percent for large trucks from 1990 to 1996. As a base of comparison, data on private carriers show the average annual distance travelled for straight trucks (similar to medium-sized trucks) increased by 50 percent and for road tractors by 29 percent over the same period.

Transborder trucking has become increasingly important. Since 1990, transborder trucking activity, measured as total for-hire trucking revenues, has grown from 24.2 to 35.9 percent of those revenues. This is reflected in a 77 percent increase in tonnes carried and a 96 percent increase in tonne-kilometres. Trucking is estimated to account for 28 percent of tonnage[23] transported between Canada and the United States.

In addition to increased activity, the composition of the medium and large truck[24] stocks changed over the period. Although the overall stock decreased by 8 percent, the share of large trucks increased from 47 to 53 percent of the total medium and heavy truck stock. This change is important to overall energy use as large trucks have a significantly higher activity level (longer average distance travelled, higher load capacity, therefore higher tonne-kilometres) than medium trucks.

6.2.2 Rail

Over the 1990–1996 period, the rail sector has responded to new market conditions shaped by the removal of most economic regulation in the industry and by new trade agreements with the United States and Mexico. Canada's two largest railways have rationalized their operations by scaling back, abandoning lines and selling assets. The direct effect was to reduce their activity levels, but some of this was regained by newly established short line railways operating parts of the old system. The two main railways also moved to integrate their entire operations to a continental basis. This involved north-south link acquisitions, partnerships and investments in infrastructure to eliminate bottlenecks. These developments have laid the groundwork for higher activity levels and more efficient rail networks.

As the infrastructure was rationalized, equipment was also replaced to increase overall economy and fuel efficiency. The size of the non-passenger locomotive fleet is 3262 units, down 246 units, or 7 percent since, 1990. At the same time, the number of freight locomotives in the stock has decreased by 9.7 percent. Although smaller, the locomotive stock moved more freight. This is reflected in a greater activity level as tonne-kilometres were up 12.9 percent over 1990 levels.

23 These comparisons are not possible for private commercial trucking as the data are not available, but on the revenue side, the private carrier fleet could be moving a disproportionately large percent of the value of annual shipments.

24 Medium-sized trucks are 4545 kg to 15 000 kg and large trucks are greater than 15 000 kg.

6.2.3 Marine

In the marine sector, the backdrop to changes in shipping activity over the 1990–1996 period was a recession that had its largest impact on activity in 1992 and 1993. Shipments of major commodities such as iron ore and coal dropped by 1 percent in the recession but, by 1995, posted increases of 5.0 percent and 9.3 percent over 1990 levels. Wheat shipments fell by up to one-third but were back at 1990 levels in 1995. In spite of the volatility in shipping in the last few years the overall change was small. About 38 percent of freight tonnage moved in 1996 was moved by ship, down from 41.3 percent in 1990.

6.3 Trend in Carbon Dioxide Emissions of Transportation Energy Use

Carbon dioxide emissions from the transport sector[25] increased by 10.2 percent, from 127 megatonnes in 1990 to 140 megatonnes in 1996. Figure 6.13 presents a breakdown of emissions by mode in 1990 and 1996. The most striking feature of the change in shares is that all of the growth in emissions comes from road and aviation. The largest on-road increase comes from trucks.

Figure 6.13 Transportation Carbon Dioxide Emissions Shares by Mode, 1990 and 1996 (percent)

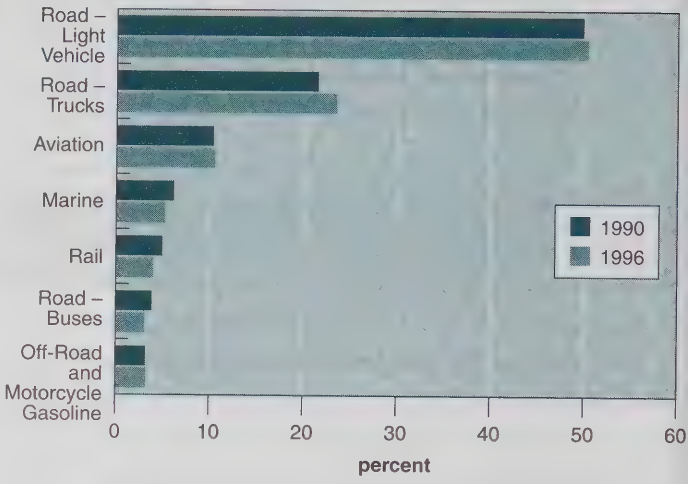
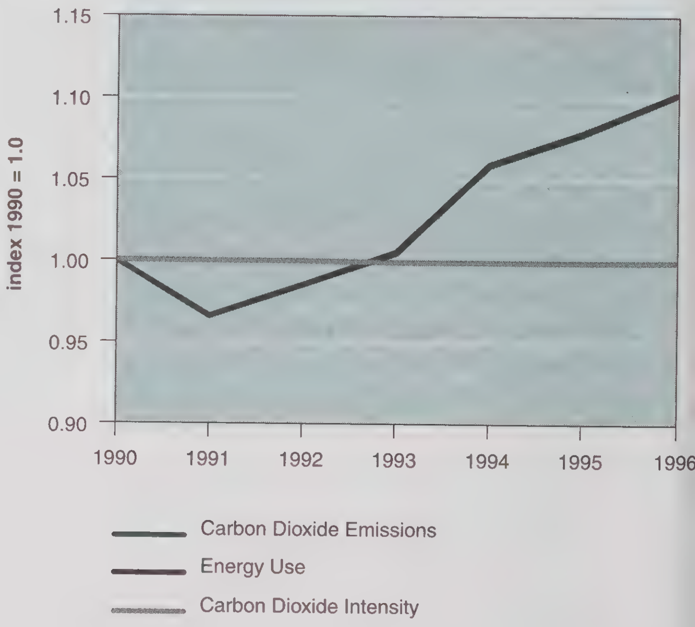


Figure 6.14 shows the changes in carbon dioxide emissions, energy use and carbon dioxide intensity over the period 1990 to 1996. Since this sector is dominated by a few fuel types and the shares of these fuel types were relatively stable over the 1990 to 1996 period, the trend in emissions closely tracked the trend in energy use over the period.

Figure 6.14 Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1996 (index 1990 = 1.0)



25 The definition of transport energy demand and related carbon dioxide emissions used in this report differs from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. See Appendix D for documentation of differences.

Figure 6.15 Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1996 (percent)

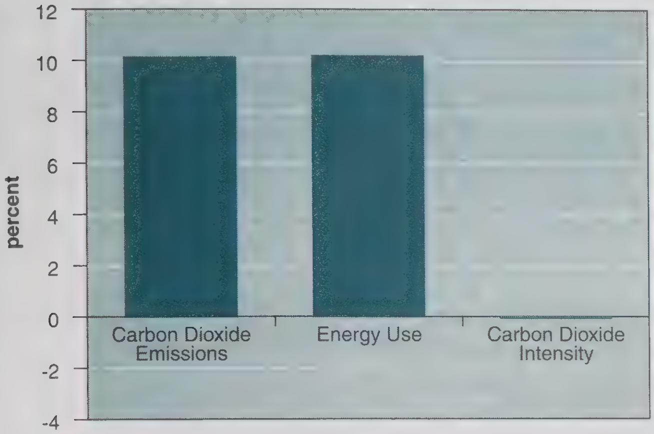


Figure 6.15 confirms the dominant influence of changes in energy use on changes in carbon dioxide emissions. The increase in carbon dioxide emissions from 1990 to 1996 is almost entirely driven by growth in energy use. Energy use increased by 10.2 percent, while the average carbon dioxide intensity of transport fuels declined by less than one-tenth of a percent.

The small decline in carbon dioxide intensity was mostly due to a shift from motor gasoline to diesel fuel. Diesel's fuel economy more than makes up for it being about 16 percent more carbon dioxide intensive than motor gasoline.[26] Diesel fuel increased its share of total transport by more than 2 percent to 26 percent, while motor gasoline's share declined more than 2 percent to 59 percent.

6.4 The Data Situation

The data used in this chapter come from various sources. In some cases, such as activity measures, only partial information is available. Calibration procedures are used to complement this information. Data collection and calibration procedure improvements are ongoing. The following describes some recent developments.

The *National Private Vehicle Use Survey* (NaPVUS) was conducted quarterly by Statistics Canada for NRCan from October 1994 through September 1996. Through this survey, NRCan collected data on private vehicle use and fuel consumption and identified some of the factors that may affect consumption. Efforts will be made to link NaPVUS results to Statistics Canada's *Fuel Consumption Survey* (FCS) that ended in 1988.

NRCan is also investigating the development of a commercial vehicle fleet survey. Pilot projects are currently under development. Provided that these projects are conclusive, a feasibility study for a broader survey on commercial fleets will follow.

This report incorporates a reassessment of bus activity and energy use, as well as an estimate of motor gasoline "off-road" use and motorcycle use. The estimate of "off-road" energy use accounts for the residential and industrial portion of motor gasoline retail pump sales reported by Statistics Canada.[27]

NRCan is also investigating trucking activity associated with private carriers, truck owner/operators and service trucking such as couriers.

26 The fuel economy (L/100 km) of a diesel car is roughly 25 percent better than that of similar gasoline-powered car. Also, diesel truck fuel economy is about 20 percent better than what similar gasoline trucks would achieve. This superior fuel economy reflects a combination of energy content and technology.

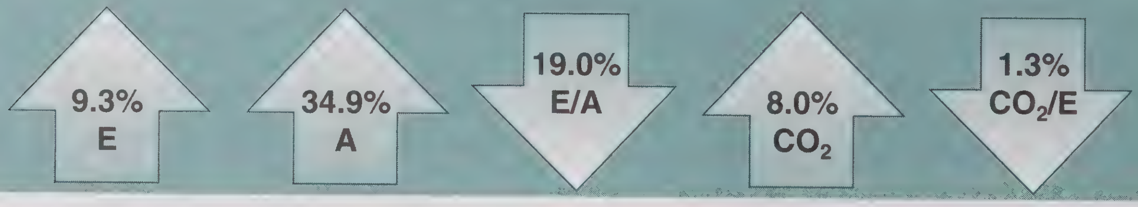
27 Residential motor gasoline use pertains to recreational vehicles and equipment such as snowmobiles, outboard motors or lawn mowers. Industrial motor gasoline use comes from machinery and equipment such as forestry machinery or stand-alone electric generators.

Agriculture Sector

HIGHLIGHTS

- Over the 1990 to 1996 period, agricultural energy use (E) increased by 9.3 percent to reach 224 petajoules in 1996.
  - Activity (A) (measured in GDP) increased 34.9 percent. Had activity remained at the 1990 level, 1996 energy use would have been 25.9 percent lower than it actually was; 166 petajoules in 1996 instead of 224 petajoules.
  - The change in the mix of activity has an influence on energy consumption, and it was significant over the 1990 to 1996 period, however, it is not factorized in this chapter.
  - Weather had a significant influence on energy consumption in the agriculture sector. The large increase of energy use at the end of this period can be explained by the wet and colder weather of 1996.
  - Aggregate energy intensity (E/A) declined by 19.0 percent from its 1990 level.
- Carbon dioxide emissions (CO_2) of energy resulting from agricultural energy use increased by 8.0 percent from 1990 to 1996.
- Carbon dioxide emissions of energy use grew more slowly than energy use because the carbon dioxide intensity (CO_2/E) of agricultural energy use decreased by 1.3 percent from 1990 to 1996 due to fuel switching.

THE ENERGY/EMISSIONS BAROMETER—AGRICULTURE



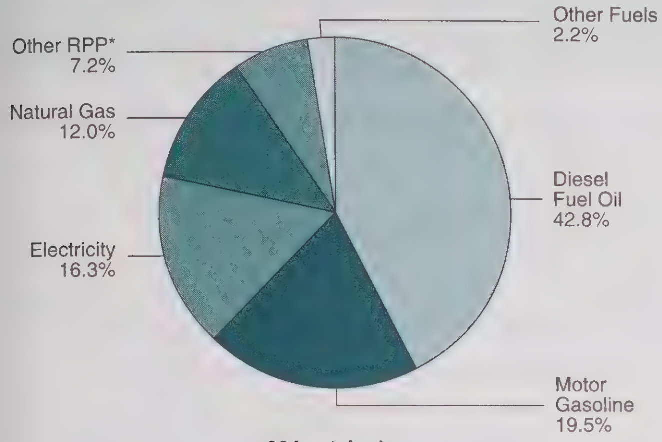
In the agriculture sector, energy use is defined as energy related to farm production, including establishments engaged in agricultural activities as well as those engaged in providing services to agriculture. The sector includes the energy use of livestock farms, field crop farms, fruit and vegetable farms and horticultural specialties (mushroom growers, nurseries) and excludes personal energy use.

In 1996, agricultural energy use accounted for 224 petajoules, or 2.9 percent, of total secondary energy requirements in Canada.

Resulting carbon dioxide emissions represented 3.4 percent of secondary energy use-related emissions. Agricultural carbon dioxide emissions exceed energy use because there is a higher concentration of carbon dioxide intensive energy forms.

Figure 7.1 shows energy shares for 1996. Motive fuels (motor gasoline and diesel) are the dominant energy requirement and represent about 62.3 percent of total energy use in the agriculture sector. Motor gasoline and diesel fuel oil represent 86.9 percent of the refined petroleum products used.

Figure 7.1 Distribution of Agricultural Energy Use by Fuel, 1996 (percent)



*RPP: Refined Petroleum Product

Measure of Agriculture Activity

Farm production value is highly sensitive to weather, production mix and product pricing. For this report, GDP was chosen as a measure of activity because the analysis is done at a relatively aggregate level of detail.

GDP is a good aggregate measure, but since it reflects value added, its variability, particularly on a subsectoral basis, can overemphasize cyclical movements. This variability is directly reflected in energy intensity.

For other purposes, such as the tracking of sector-specific energy efficiency progress in the agriculture sector, the use of physical output measures is more suitable.

7.1 Evolution of Agricultural Energy Use and its Major Determinants

As shown in Figure 7.2, motor gasoline use declined over the period due to a shift to diesel fuel oil. After 1990, farmers found it advantageous, for tax and other reasons, to change to diesel-powered trucks and other farm vehicles, which may explain the increase in diesel consumption during the 1990–1996 period.

The agriculture industry turned to diesel for a number of reasons. Gas engines are not as fuel-efficient, diesel is cheaper to purchase, the life expectancy of the gasoline engine is not as long, the increased field trips for grain growing by farmers make diesel engines the cheaper alternative, and the diesel engine provides more power, which is becoming more important in the transportation of crops and livestock especially in the prairies with the continual closing of rail lines. The growth in size of the individual farm means farmers need larger equipment requiring more power. As a result, gas tractors are no longer manufactured.

Natural gas, non-motive refined petroleum products and other fuels are mainly used for heating (e.g., greenhouses, barns) and for drying (e.g., grain). Electricity is used in multiple applications from power drive to lighting.

Figure 7.2 Agricultural Energy Fuel Shares, 1990 and 1996 (percent)

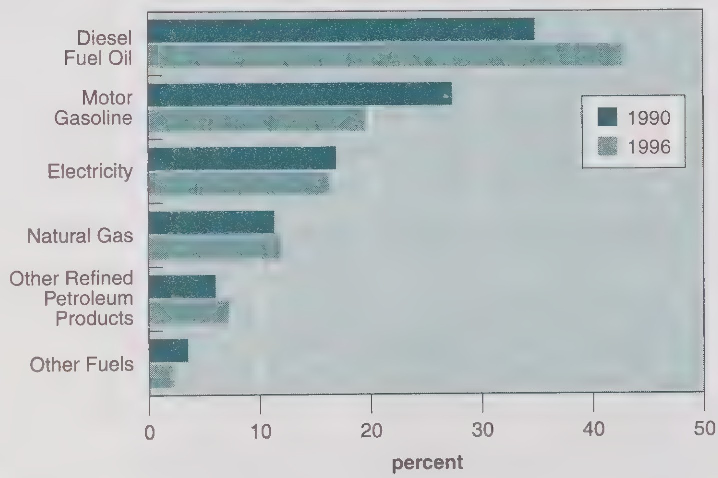
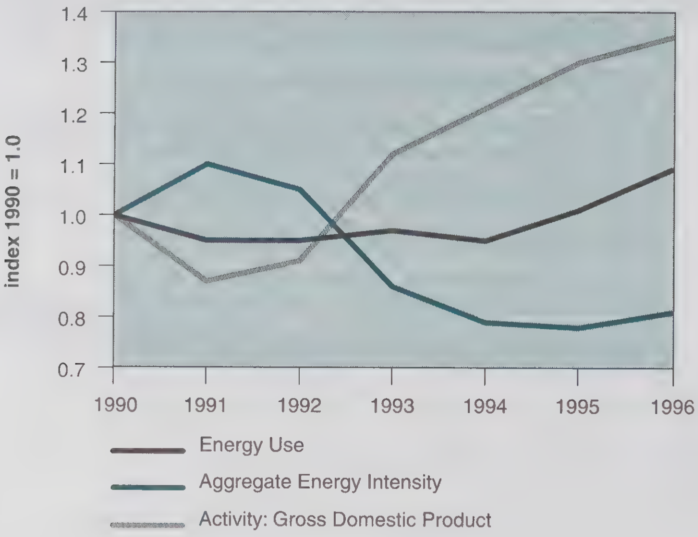


Figure 7.3 shows a strong growth in activity from 1992 to 1996 and a decline in intensity for the same period. Had activity, measured in GDP, remained at the 1990 level, 1996 energy use would have been 25.9 percent lower than the actual 1996 level, 166 petajoules in 1996 instead of 224 petajoules. On the other hand, if intensity had stayed at the 1990 level, 1996 energy use would have been 23.4 percent higher than the actual 1996 level, 276 petajoules instead of 224 petajoules.

Figure 7.3 Agricultural Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)



Energy intensity is influenced by different factors such as production mix, weather, technology efficiency, and agricultural practices.

Changes in agricultural practices correspond directly to the change in energy use. In recent years, the zero tillage technique has become more common than the minimum and conventional techniques used in the past.[1] This shift has contributed to lower growth in motive fuel demand. A reduction in tillage operations reduces fuel consumption with the saving being dependent upon the amount and type of tillage conventionally used. This saving becomes more significant as fuel costs continue to rise. A small portion of the saving will be offset by the fuel required for any additional herbicide applications that may be necessary; however, these requirements will be less than required for tillage.

The 1991 and 1996 *Census of Agriculture* reports the area in summer fallow decreased by 21.0 percent between 1991 and 1996. The term "summer fallow" is used to describe land that a farmer leaves uncropped. Two of the main reasons for this practice is to store moisture and to replenish natural nutrients in the soil to ensure adequate yields. Unfortunately, it is an inefficient way to increase moisture storage, as trials over a number of years have shown.[2] If farmers reduce summer fallow, it leads to an increase in land for cropping, which results in increased energy use.

These two practices (less tillage, less summer fallow) influence energy use in opposite directions.

Weather has a significant influence on energy consumption in agriculture. In wet years, the fuel consumption of farm vehicles increases because of poor off-road conditions and large quantities of grain that need to be dried, a process that uses propane or natural gas. In dry years, there is an increase in energy use for irregation, but this increase is not considerable compared to the increase in energy use in wet years. In cold years, an increase in energy use results from the increased heating requirements of greenhouses and barns, etc.

From 1990 to 1995, the weather was between 2 to 7 percent warmer than normal, except in 1993, when it was 0.1 percent colder. In 1996, the weather was 5 percent colder than normal. This explains part of the increase in energy use from 1995 to 1996.

In 1990, the weather was dry, in 1991 and 1996 it was wet, and from 1992 to 1995 it was normal. As explained above, when the weather is wet, farmers need more energy to operate their farms. This explains part of the increase in energy use from 1995 to 1996. Energy use did not increase in 1991 even though it was a wet year. This was likely a result of the recession.

1 Canadian Agricultural Energy End-Use Data and Analysis Centre (CAEEDAC), Department of Agriculture Economics, University of Saskatchewan, Saskatoon, 1997.

2 Division of extension and community relations, Guide to Farm Practice in Saskatchewan, University of Saskatchewan, Saskatoon, 1987.

7.2 Trend in the Carbon Dioxide Emissions of Agricultural Energy Use

Agricultural carbon dioxide emissions[3] increased by 8.0 percent over the 1990–1996 period.

Agriculture sector emissions in 1996 would have been 10.6 percent lower if end-use electricity related to carbon dioxide emissions had not be accounted for. This is significant in this sector. However, it is less significant than for the other sectors as electricity accounts for only 16.3 percent of agricultural energy use and agricultural energy use is only about 3 percent of total energy consumption.

7.2.1 Trends in the carbon dioxide intensity of agricultural energy use

The shares of diesel fuel oil and motor gasoline carbon dioxide emissions are higher than their respective shares of energy use. As shown in Figure 7.4, diesel fuel oil and motor gasoline account for 47.1 percent and 20.8 percent, respectively, of 1996 agriculture sector emissions.

From 1990 to 1996, there was a shift towards diesel at the expense of gasoline. The emission factor for diesel and gasoline is about the same, and their respective carbon dioxide intensities have not changed over the period.

Electricity and natural gas represent 75.2 percent of non-motive fuel. At end-use, electricity consumption results in 12.5 percent of total agricultural carbon dioxide emissions and natural gas results in 9.2 percent of emissions. The carbon dioxide intensity of electricity and natural gas is significantly lower than for diesel and gasoline. Over the 1990 to 1996 period, carbon dioxide intensity decreased by 12.0 percent for electricity and only 0.7 percent for natural gas. The significant decrease for electricity can by explained by the changing fuel mix to generate electricity.

Figure 7.5 presents the growth in emissions, energy use and average carbon dioxide intensity over the 1990 to 1996 period. Emissions increased less than energy use, 8.0 percent compared to 9.3 percent for energy. This can be explained by the 1.3 percent decrease in the carbon dioxide intensity of energy use.

Figure 7.4 Agricultural Carbon Dioxide Emissions by End-Use, 1996

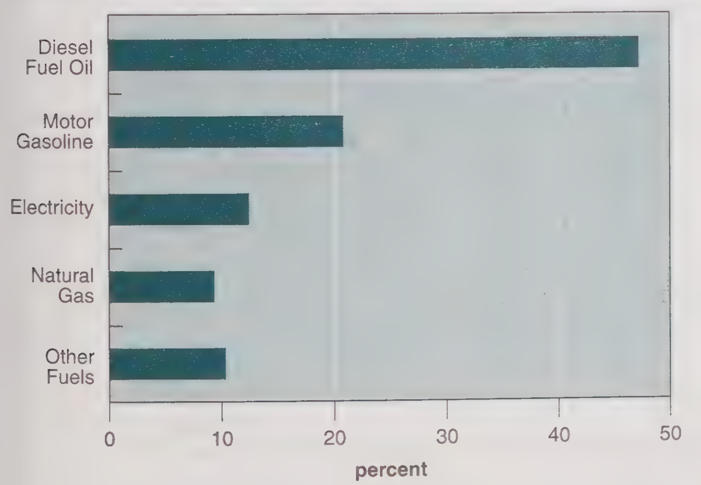
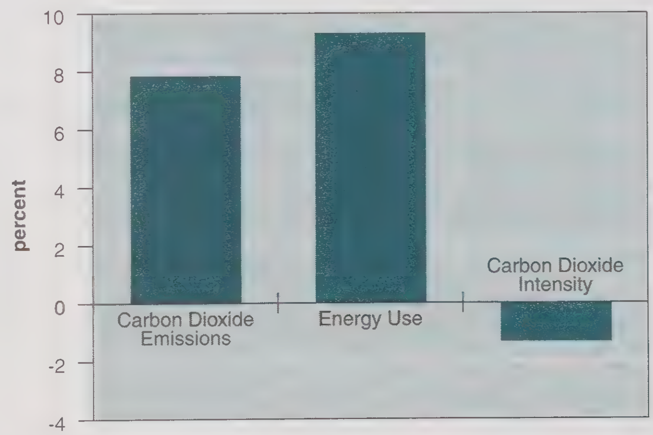


Figure 7.5 Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, 1990–1996 (percent)



3 The definition of agricultural energy demand and related carbon dioxide emissions used in this report differs from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. See Appendix D for documentation of differences.

7.3 The Data Situation

Detailed information exists about production in the agriculture sector. Statistics Canada's Quarterly Report on Energy Supply – Demand in Canada (QRESD) provides aggregate data on energy use.

The *Farm Energy Use Survey* also provides aggregate energy use data. Prior to 1997, the last survey of farm energy use in Canada was conducted by Statistics Canada in 1981. As a result, NRCan, along with Agriculture & Agri-Food Canada and Environment Canada, sponsored the *1997 Farm Energy Use Survey*, which was conducted by Statistics Canada. The 1997 survey provides up-to-date data to improve the background information available for decision-making. The CAEEDAC will concentrate its effort on analysing these results over the coming year.

Data Presented in Report

Figure A-2.1
Secondary Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Oil Products	36.9	35.0
Natural Gas	25.8	27.7
Electricity	22.5	22.3
Other Fuels[a]	14.8	15.0

[a] Liquefied petroleum gases, coal, coke and coke oven gases, steam

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-3.1
Distribution of Households by Type of Dwelling, 1996 (percent)

Housing Types	1996
Mobile Homes	1.9
Apartments	32.3
Single-Attached	10.5
Single-Detached	55.3

Source:
- Statistics Canada. *Household Facilities and Equipment 1996*. Ottawa. October 1996. [Cat. 64-202]

Figure A-3.2
Distribution of Residential Energy Use by End-Use, 1996 (percent)

End-uses	1996
Space Cooling	0.4
Water Heating	21.2
Appliances	13.2
Space Heating	61.1
Lighting	4.1

Source:
- Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.

Figure A-3.3
Residential Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

Factors	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	0.97	1.00	1.05	1.06	1.04	1.12
Aggregate Energy Intensity	1.00	0.95	0.96	0.98	0.98	0.94	1.00
Activity: Households	1.00	1.03	1.05	1.07	1.08	1.10	1.12

Sources:
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days below 18.0°C*. Toronto. 1990–1996.
- Statistics Canada. *Household Facilities and Equipment 1990–1996*. Ottawa. October 1990 – October 1996. [Cat. 64-202]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]

Figure A-3.4
Residential Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Natural Gas	40.8	47.9
Electricity	36.2	33.9
Oil	14.3	10.9
Other Fuels[a]	8.7	7.4

[a] Liquefied petroleum gases, coal, steam, wood

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-3.5
Residential Energy End-Use Shares, 1990 and 1996 (percent)

End-Uses	1990	1996
Space Cooling	0.4	0.4
Lighting	4.2	4.1
Appliances	14.2	13.2
Water Heating	20.2	21.2
Space Heating	61.0	61.1

Sources: • Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.

Figure A-3.6
Factors Influencing Growth in Residential Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	158.74
Activity: Households	153.40
Weather	86.75
Structure: End-Use Mix	8.73
Energy Intensity	-81.58
Interaction	-8.57

Sources:
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days below 18.0°C.* Toronto. 1990–1996.
- Statistics Canada. *Household Facilities and Equipment 1990–1996*. Ottawa. October 1990 – October 1996. [Cat. 64-202]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.

Figure A-3.7
Factors Influencing Growth in Residential Space Heating Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	97.90
Activity: Households	93.58
Weather	86.75
Energy Intensity	-77.63
Interaction	-4.79

Sources:
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days below 18.0°C.* Toronto. 1990–1996.
- Statistics Canada. *Household Facilities and Equipment 1990–1996*. Ottawa. October 1990 – October 1996. [Cat. 64-202]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.

Figure A-3.8
Housing Stock by Vintage, 1990 and 1996 (percent)

Vintages	1990	1996
Pre 1946	21.5	18.5
1946–1960	14.5	12.6
1961–1977	35.6	30.5
1978–1983	12.5	11.0
Post 1983	15.9	27.4

Sources:
- Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.
- Statistics Canada. *Household Facilities and Equipment 1990*. Ottawa. October 1990. [Cat. 64-202]
- Statistics Canada. *Household Facilities and Equipment 1996*. Ottawa. October 1996. [Cat. 64-202]

Figure A-3.9
National Trends in Air Leakage by Vintage (air changes per hour at 50 Pa)

Vintages	Air Changes
Pre 1946	12.96
1946 – 1980	7.09
1981 – 1985	5.38
1986 – 1990	3.67
1991 – 1995	3.05

Sources: • CANMET. Energy Technology Centre. *Air Leakage Characteristics of Canadian Housing Stock*. Ottawa. October 1996.

Figure A-3.10
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1996 (thousands of units)

Efficiencies	1990	1996
Normal Efficiency	87.3	0.0
Mid-Efficiency	22.0	90.1
High-Efficiency	29.9	69.5

Source: • Canadian Gas Association. *Canadian Gas Facts 1996*. North York. 1996.

Figure A-3.11
Factors Influencing Growth in Residential Appliance Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	8.16
Activity: Households	21.83
Appliance Penetration	5.76
Energy Intensity	-17.71
Interaction	-1.71

Sources: • Statistics Canada. *Household Facilities and Equipment 1990–1996*. Ottawa. October 1990 – October 1996. [Cat. 64-202]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]

Figure A-3.12
Penetration Rates for Household Appliances, 1990 and 1996 (average number per household)

Appliances	1990	1996
Refrigerators	1.18	1.20
Ranges – electric	0.94	0.94
Microwave Ovens	0.64	0.85
Video Casette Recorders	0.66	0.84
Clothes Washers	0.75	0.78
Clothes Dryers – electric	0.71	0.74
Freezers	0.57	0.57
Dishwashers	0.42	0.48
Compact Disc Players	0.15	0.53
Home Computer	0.16	0.32

Sources: • Statistics Canada. *Household Facilities and Equipment 1990*. Ottawa. October 1990. [Cat. 64-202]
• Statistics Canada. *Household Facilities and Equipment 1996*. Ottawa. October 1996. [Cat. 64-202]

Figure A-3.13
Energy Efficiency Trends of Appliances, 1990 and 1996 (kWh per year)

Appliances	1990	1996
Clothes Washers	1150	913
Clothes Dryers	1095	894
Refrigerators	1018	656
Ranges	738	772
Freezers	530	364
Dishwashers	1025	617

Sources:
- Natural Resources Canada. *EnerGuide Directories 1990*. Ottawa.
- Natural Resources Canada. *EnerGuide Directories 1995*. Ottawa.

Figure A-3.14
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1996 (percent)

	1990–1996
Carbon Dioxide Emissions	6.23
Energy Use	12.27
Carbon Dioxide Intensity	-5.38

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-3.15
Residential Carbon Dioxide Emissions by Fuel, 1996 (percent)

Fuels	1996
Electricity	34.0
Oil Products	16.3
Other Fuels	1.5
Natural Gas	48.2

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-3.16
Residential Carbon Dioxide Emissions by End-Use, 1996 (percent)

End-Uses	1996
Space Heating	60.1
Space Cooling	0.4
Water Heating	22.1
Appliances	13.3
Lighting	4.1

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]
- Natural Resources Canada. Residential End-Use Model. Ottawa. December 1997.

Figure A-4.1
Distribution of Commercial Energy Use and Activity by Building Type, 1996 (percent)
Energy Use

Building Types	1996
Retail	23.73
Office	23.87
School	13.84
Health	11.09
Hotel & Restaurant	10.65
Recreation	10.65
Warehouse	5.44
Other Institutional[a]	4.18
Religious	1.19

Activity

Building Types	1996
Retail	22.18
Office	27.85
School	14.64
Health	6.85
Hotel & Restaurant	5.60
Recreation	6.18
Warehouse	10.39
Other Institutional[a]	4.59
Religious	1.74

[a] Laboratory, research centre, library, museum

Sources:
- Natural Resources Canada. Commercial End-use Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.

Figure A-4.2
Energy by Fuel Share and Carbon Dioxide by Fuel Type, 1996 (percent)
Energy by Fuel Share

Fuel Types	1996
Electricity	42.4
Natural Gas	45.2
Oil Products	6.8
LPG	3.4
Other	2.2

Carbon Dioxide by Fuel Type

Fuel Types	1996
Electricity	39.8
Natural Gas	43.7
Oil Products	9.8
LPG	4.0
Other	2.7

Source:
- Natural Resources Canada. Commercial End-use Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-4.3
Commercial Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09	1.12
Activity: Floor Space	1.00	1.03	1.05	1.07	1.08	1.09	1.11
Aggregate Energy Intensity	1.00	0.98	0.98	0.99	0.97	0.99	1.01

Sources:
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days above 21.0°C*. Toronto. 1990–1996.
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days below 18.0°C*. Toronto. 1990–1996.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.

Figure A-4.4
Factors Influencing Growth in Commercial Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	107.92
Activity: Floor Space	97.04
Weather	43.59
Structure: Building Type	1.02
Energy Intensity	-32.94
Interaction	0.84

Sources:
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days above 21.0°C.* Toronto. 1990–1996.
- Environment Canada. Atmospheric Environment Service. *Monthly Summary of Degree-Days below 18.0°C.* Toronto. 1990–1996.
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.
- Natural Resources Canada. Commercial End-use Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]

Figure A-4.5
Annual Growth of Commercial Floor Space and RDP,[a] 1990–1996 (percent)

	1990	1991	1992	1993	1994	1995	1996
Floor space (actual)	4.68	3.12	2.30	1.68	1.11	1.08	1.68
RDP (3 years ago)	4.09	4.34	3.15	0.73	-0.10	1.74	2.20

[a]Real Domestic Product

Source:
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.

Figure A-4.6
Changes in Commercial Activity Shares by Building Type, 1990–1996 (percentage points)

Building Types	1990–1996
Hotel/Restaurant	-0.01
Health	-0.18
Retail	-1.51
Recreation	0.62
School	0.29
Other Institutional[a]	0.34
Office	1.87
Religious	-0.17
Warehouse	-1.24

[a]Laboratory, research centre, library, museum

Source:
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.

Figure A-4.7
Commercial Sector Employment by Floor Space, 1990–1996 (thousands m^2)

	1990	1991	1992	1993	1994	1995	1996
Canada	17.1	16.5	16.2	16.3	16.4	16.6	16.4

Sources:
- Informetrica Limited. *Historical Estimates of Commercial Floor Space. 1995 Database Update*. Ottawa. December 1997.
- Statistics Canada. *Labour Force Survey*. Ottawa.

Figure A-4.8
Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990 –1996 (index 1990= 1.0)

	1990	1991	1992	1993	1994	1995	1996
Carbon Dioxide Emissions	1.00	0.99	1.03	1.00	0.97	1.04	1.05
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09	1.12
Carbon Dioxide Intensity	1.00	0.98	1.00	0.94	0.92	0.96	0.93

Sources:
- Natural Resources Canada. Commercial End-use Model. Ottawa. December 1997.
- Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]

Figure A-4.9
Commercial Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Electricity	42.2	41.9
Natural Gas	43.9	45.6
Oil Products	8.3	6.9
LPGs[a]	2.4	3.4
Other Fuels[b]	3.2	2.2

[a]Liquefied petroleum gases
[b]Coal, steam

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-4.10
Commercial Carbon Dioxide Emissions by Building Type, 1990 and 1996 (percent)

Building Types	1990	1996
Retail	25.4	23.2
Office	22.4	23.7
School	13.9	14.0
Health	11.4	11.3
Hotel/Restaurant	10.1	11.0
Recreation	5.5	6.0
Warehouse	6.1	5.4
Other Institutional[a]	3.9	4.2
Religious	1.3	1.2

[a]Laboratory, research centre, library, museum

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
• Natural Resources Canada. Commercial End-use Model. Ottawa. December 1997.
• Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-5.1
Distribution of Industrial Energy Use and Activity by Industry, 1996 (percent)
Energy Use

Sectors	1996
Pulp and Paper	29.1
Mining	13.4
Petroleum Refining	10.9
Iron and Steel	8.5
Chemicals	7.8
Smelting and Refining	7.9
Cement	1.9
Construction	1.6
Forestry	0.3
Other Manufacturing	18.7

Activity

Sectors	1996
Pulp and Paper	5.8
Mining	15.5
Petroleum Refining	1.4
Iron and Steel	1.8
Chemicals	1.8
Smelting and Refining	1.9
Cement	0.3
Construction	16.9
Forestry	1.9
Other Manufacturing	52.7

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
• Informetrica. *National Reference Forecast*. August 1997.

Figure A-5.2
Industrial Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	0.99	0.98	1.02	1.05	1.11	1.12
Aggregate Energy Intensity	1.00	1.06	1.05	1.05	1.02	1.05	1.05
Activity: Gross Domestic Product	1.00	0.94	0.94	0.97	1.03	1.06	1.07

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Statistics Canada. *Gross Domestic Product by Industry – June 1996*. Ottawa. October 1996; 10(7). [Cat.15-001]

Figure A-5.3
Machinery and Equipment Investments as a Share of Total Stock of Machinery and Equipment, 1984–1996 (percent)

Years	Refined Petroleum and Coal Products	Smelting and Refining	Pulp and Paper	Iron and Steel	Cement	Chemicals	Mining
1984	5.16	7.81	5.13	2.92	4.02	6.06	9.22
1985	3.96	9.09	8.08	4.86	5.19	5.50	10.37
1986	5.78	6.79	7.85	8.82	7.48	6.77	6.68
1987	8.91	7.25	10.42	7.42	7.23	5.81	7.50
1988	10.60	10.48	12.36	5.44	8.85	6.52	10.84
1989	12.35	15.11	15.41	5.34	10.54	8.49	6.90
1990	11.79	13.11	12.20	6.16	10.88	9.22	6.22
1991	10.09	14.45	7.80	4.88	6.55	9.02	6.31
1992	5.71	6.82	5.09	3.25	4.16	8.15	5.19
1993	3.95	4.42	4.37	2.54	4.38	7.98	7.14
1994	3.54	3.23	4.46	3.48	6.06	7.11	9.05
1995	3.73	4.32	8.27	4.66	7.59	6.55	12.95
1996	6.28	7.19	6.46	8.20	7.69	8.56	14.60

Sources: • Informetrica. *National Reference Forecast*. August 1997.

Figure A-5.4
Industrial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Carbon Dioxide Emissions	1.00	0.97	0.97	0.98	0.98	1.04	1.06
Energy Use	1.00	0.99	0.98	1.02	1.05	1.11	1.12
Carbon Dioxide Intensity	1.00	0.98	0.99	0.96	0.93	0.94	0.94

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-5.5
Factors Influencing Growth in Industrial Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	308.55
Activity: Gross Domestic Product	171.25
Structure: Sector Mix	99.78
Energy Intensity	35.45
Interaction	2.07

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Informetrica. *National Reference Forecast*. August 1997.

Figure A-5.6
Changes in Sectoral Shares of Industrial Activity, 1990–1996 (percentage points)

Sectors	1990–1996
Cement	-0.06
Petroleum Refining	0.01
Pulp and Paper	-0.07
Iron and Steel	0.12
Chemicals	-0.17
Smelting and Refining	0.45
Mining	2.22
Other Manufacturing	2.67
Forestry	-0.24
Construction	-4.96

Source: • Informetrica. *National Reference Forecast*. August 1997.

Figure A-5.7
Industrial Carbon Dioxide Emissions by Industry, 1990 and 1996 (percent)

Sectors	1990	1996
Pulp and Paper	16.8	15.1
Mining	12.4	17.1
Petroleum Refining	13.8	13.0
Iron and Steel	12.1	12.3
Chemicals	7.6	7.9
Smelting and Refining	8.1	8.8
Cement	3.2	2.8
Construction	2.4	2.2
Forestry	0.9	0.5
Other Manufacturing	22.8	20.2

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
• Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-5.8
Industrial Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
"Coal, Coke & Coke Oven Gas"	6.7	6.0
Other Fuels[a]	14.9	16.2
Oil Products	22.0	20.7
Electricity	25.0	25.4
Natural Gas	31.5	31.7

[a]Liquefied petroleum gases, wood waste, pulping liquor

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-6.1
Distribution of Passenger Transportation Energy Use and Activity by Mode, 1996 (percent)

Energy Use

Modes	1996
Road – Light Vehicles	79.1
Aviation	15.8
Road – Buses	5.0
Rail	0.2

Activity

Modes	1996
Road – Light Vehicles	79.1
Aviation	12.9
Road – Buses	7.7
Rail	0.2

Sources:
- Royal Commission on National Passenger Transportation. *Directions: the final report of the Royal Commission on National Passenger Transportation*. Ottawa. 1992; 2.
- Statistics Canada. *Air Carrier Operations in Canada 1996*. Ottawa. 1997; 26(1) – (4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin*. Ottawa. 1996; 28 (1) – (12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1994*. December 1995. [Cat. 53-215]
- Statistics Canada. *Rail in Canada*. Ottawa. December 1997. [Cat. 52-216]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. August 1997; 21(4). [Cat. 57-003]
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.

Figure A-6.2
Distribution of Freight Transportation Energy Use and Activity by Mode, 1996 (percent)

Energy Use

Modes	1996
Road – Trucks	72.7
Marine	15.5
Rail	11.8

Activity

Modes	1996
Road – Trucks	23.5
Marine	30.9
Rail	45.6

Sources:
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]
- Statistics Canada. *Trucking in Canada 1994*. Ottawa. February 1997. [Cat. 53-222]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. August 1997; 21(4). [Cat. 57-003]
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Transport Canada. *Marine and Surface Statistics and Forecast Division*. Discussion. November 1997.

Figure A-6.3
Passenger Transportation Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	0.96	0.99	1.01	1.05	1.07	1.10
Aggregate Energy Intensity	1.00	0.97	0.96	0.95	0.94	0.94	0.93
Activity: Passenger-kilometre	1.00	0.99	1.03	1.07	1.12	1.15	1.18

Sources:
- Royal Commission on National Passenger Transportation. *Directions: the final report of the Royal Commission on National Passenger Transportation*. Ottawa. 1992; 2.
- Statistics Canada. *Air Carrier Operations in Canada 1990–1996*. Ottawa. 1991–1997; 21(1) – 26(4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin*. Ottawa. 1990 –1996; 22(1) – 28(12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1990–1996*. February 1993 – February 1998. [Cat. 53-215]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.4
Passenger Transportation Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Motor Gasoline	76.3	76.2
Aviation Fuels	15.5	15.8
Diesel	6.6	6.0
Alternative Transportation Fuels[a]	1.6	2.0

[a]Includes propane, natural gas and electricty

Sources:
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Air Carrier Operations in Canada 1990–1996*. Ottawa. 1991–1997; 21(1) – 26(4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin*. Ottawa. 1990 –1996; 22(1) – 28(12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1990–1996*. February 1993 – February 1998. [Cat. 53-215]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.5
Passenger Transportation Energy Mode Shares, 1990 and 1996 (percent)

Modes	1990	1996
Road – Light Vehicles	78.0	79.1
Aviation	15.5	15.8
Road – Buses	6.4	5.0
Rail	0.4	0.2

Sources:
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Air Carrier Operations in Canada 1990–1996*. Ottawa. 1991–1997; 21(1) – 26(4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin*. Ottawa. 1990 –1996; 22(1) – 28(12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1990–1996*. February 1993 – February 1998. [Cat. 53-215]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.6
Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	116.85
Activity: Passenger-kilometre	206.29
Structure: Vehicle Mix	9.63
Energy Intensity	-76.84
Interaction	-12.87

Sources:
- Royal Commission on National Passenger Transportation. *Directions: the final report of the Royal Commission on National Passenger Transportation*. Ottawa. 1992; 2.
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Air Carrier Operations in Canada 1990–1996*. Ottawa. 1991–1997; 21(1) – 26(4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin. Ottawa. 1990 –1996*; 22(1) – 28(12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1990–1996*. February 1993 – February 1998. [Cat. 53-215]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.7
Factors Influencing Growth in Light-Vehicles Passenger Transportation Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	105.59
Activity: Passenger-kilometre	195.31
Structure: Vehicle Mix	10.26
Energy Intensity	-85.28
Interaction	-13.74

Sources:
- Royal Commission on National Passenger Transportation. *Directions: the final report of the Royal Commission on National Passenger Transportation.* Ottawa. 1992; 2.
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Air Carrier Operations in Canada 1990–1996*. Ottawa. 1991–1997; 21(1) – 26(4). [Cat. 51-002]
- Statistics Canada. *Aviation Statistics Centre: Service Bulletin*. Ottawa. 1990 –1996; 22(1) – 28(12). [Cat. 51-004]
- Statistics Canada. *Passenger Bus and Urban Transit Statistics 1990–1996*. February 1993 – February 1998. [Cat. 53-215]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.8
Trends in Car Fuel Economy, 1978–1996 (litres/100 km)

Years	All Cars	New Cars
1978	16.69	14.82
1979	16.38	14.14
1980	16.01	13.13
1981	15.59	12.40
1982	15.10	10.29
1983	14.50	9.86
1984	13.89	10.07
1985	13.23	9.87
1986	12.68	10.08
1987	12.20	10.22
1988	11.72	9.87
1989	11.36	10.18
1990	11.08	10.32
1991	10.85	10.27
1992	10.64	9.95
1993	10.48	10.07
1994	10.35	9.94
1995	10.25	9.90
1996	10.15	9.51

Sources:
- Desrosiers Automotive Consultants Inc. *Canadian Vehicles in Operation Census*. Toronto, Ontario.
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Crain Publications Communications Inc. *Automotive NewsAnnual Market Data Book*. Detroit. 1978–1995.

Figure A-6.9
Freight Transportation Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	0.97	0.97	0.99	1.06	1.09	1.11
Aggregate Energy Intensity	1.00	0.99	1.03	1.01	0.97	0.97	0.97
Activity: Tonne-kilometre	1.00	0.98	0.94	0.98	1.09	1.12	1.15

Sources:
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]
- Statistics Canada. *Shipping in Canada 1990–1996*. Ottawa. March 1992 – November 1997. [Cat. 54-205]
- Statistics Canada. *Trucking in Canada 1990*. Ottawa. February 1993. [Cat. 53-222]
- Statistics Canada. *Trucking in Canada 1996*. Ottawa. February 1998. [Cat. 53-222]
- Transport Canada. *Marine and Surface Statistics and Forecast Division*. Discussion. November 1997.

Figure A-6.10
Freight Transportation Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Diesel	61.9	70.1
Motor Gasoline	25.6	18.6
Heavy Fuel Oil	10.3	8.4
Other Fuels[a]	2.2	2.9

[a]Propane, natural gas, coal, kerosene and light fuel oil

Sources:
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]

Figure A-6.11
Factors Influencing Growth in Freight Transportation Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	64.34
Activity: Tonne/kilometre	86.32
Structure: Vehicle Mix	88.08
Energy Intensity	-90.72
Interaction	-18.69

Sources:
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]
- Statistics Canada. *Trucking in Canada 1990*. Ottawa. February 1993. [Cat. 53-222]
- Statistics Canada. *Trucking in Canada 1996*. Ottawa. February 1998. [Cat. 53-222]
- Transport Canada. *Marine and Surface Statistics and Forecast Division*. Discussion. November 1997.

Figure A-6.12
Factors Influencing Growth in Road Freight Transportation Energy Use, 1990–1996 (petajoules)

Factors	1990–1996
Energy Use	78.58
Activity: Tonne/kilometre	175.07
Structure: Vehicle Mix	-35.79
Energy Intensity	-32.12
Interaction	-27.92

Sources:
- Natural Resources Canada. Transportation Energy Demand Model. Ottawa. December 1997.
- Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
- Statistics Canada. *Rail in Canada 1990–1996*. Ottawa. July 1992 – December 1997. [Cat. 52-216]
- Statistics Canada. *Shipping in Canada 1990–1996*. Ottawa. March 1992 – November 1997. [Cat. 54-205]
- Statistics Canada. *Trucking in Canada 1990–1996*. Ottawa. February 1993 – February 1998. [Cat. 53-222]

Figure A-6.13
Transportation Carbon Dioxide Emissions Shares by Mode, 1990 and 1996 (percent)

Sectors	1990	1996
Road – Light Vehicle	49.9	50.3
Road – Trucks	21.5	23.5
Aviation	10.3	10.5
Marine	6.1	5.2
Rail	5.0	4.0
Road – Buses	3.9	3.1
Off-Road and Motorcycle Gasoline	3.2	3.2

Source:
- Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-6.14
Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Carbon Dioxide Emissions	1.00	0.97	0.99	1.00	1.06	1.08	1.10
Energy Use	1.00	0.97	0.99	1.01	1.06	1.08	1.10
Carbon Dioxide Intensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-6.15
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1996 (percent)

	1990–1996
Carbon Dioxide Emissions	10.16
Energy Use	10.22
Carbon Dioxide Intensity	-0.06

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-7.1
Distribution of Agricultural Energy Use by Fuel, 1996 (percent)

Fuels	1996
Diesel Fuel Oil	42.76
Motor Gasoline	19.53
Electricity	16.30
Natural Gas	11.98
Other RPP[a]	7.20
Other Fuels[b]	2.23

[a]Refined petroleum products
[b]Propane, steam

Source: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-7.2
Agricultural Energy Fuel Shares, 1990 and 1996 (percent)

Fuels	1990	1996
Diesel Fuel Oil	34.86	42.76
Motor Gasoline	27.38	19.53
Electricity	16.92	16.30
Natural Gas	11.32	11.98
Other RPP[a]	6.02	7.20
Other Fuels[b]	3.50	2.23

[a]Refined petroleum products
[b]Propane, steam

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990*. Ottawa. July 1991; 15(4). [Cat. 57-003]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1996*. Ottawa. August 1997; 21(4). [Cat. 57-003]

Figure A-7.3
Agricultural Energy Use, Aggregate Energy Intensity and Activity, 1990–1996 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996
Energy Use	1.00	0.95	0.95	0.97	0.95	1.01	1.09
Activity: GDP	1.00	0.87	0.91	1.12	1.21	1.30	1.35
Aggregate Energy Intensity	1.00	1.10	1.05	0.86	0.79	0.78	0.81

Sources: • Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]
• Statistics Canada. *Gross Domestic Product by Industry*. Ottawa. September 1997; 11(6). [Cat.15-001]

Figure A-7.4
Agricultural Carbon Dioxide Emissions by End-Use, 1996 (percent)

End-Uses	1996
Other Fuels[a]	10.3
Natural Gas	9.3
Electricity	12.5
Motor Gasoline	20.8
Diesel Fuel Oil	47.1

[a]Propane, steam

Source: • Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]

Figure A-7.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, 1990–1996 (percent)

	1990–1996
Carbon Dioxide Emissions	7.95
Energy Use	9.33
Carbon Dioxide Intensity	-1.26

Sources: • Environment Canada. *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Ottawa. March 1997. [EN49-5/5-8]
• Statistics Canada. *Quarterly Report on Energy Supply-Demand in Canada 1990–1996*. Ottawa. November 1990 – August 1997; 15(1) – 21(4). [Cat. 57-003]

Methodology and Data Sources for the Energy Use Factorization Analysis

1 Introduction

This appendix briefly describes the key elements of methodology used in this study to analyse secondary energy end-use trends in the Canadian economy as a whole and in each of the four end-use sectors. Four important criteria determined the choice of methodology:[1]

- Interpretation of the index is straightforward.
- The same index can be applied to all sectors and subsectors so that all can be interpreted similarly.
- Data is available with which to calculate the indexes.
- The index is theoretically sound.

In the simplest of terms, an energy efficiency index is a statistical indicator that measures energy use, taking account of changes in energy intensity, structural influences, and economic or physical activity. Such indicators can be applied to measure energy consumption at the economy-wide level and in individual sectors (e.g., transportation, commercial), industries (e.g., forestry, pulp & paper manufacturing) and specific end-uses (e.g., space heating, refrigeration). The basic formulation used here, a Laspeyres factorization method, has been used extensively in international comparisons of energy use.

2 The Factorization Method

Although the ratio of energy to gross domestic product (GDP) provides a broad indicator of overall energy intensity in the economy, many researchers have pointed out that changes to this indicator result from both structural changes in the economy as well as technical efficiency improvements. Thus, for example, because the industrial sector is more energy-intensive than the other sectors, it would contribute to a lower energy/GDP ratio if its energy use declined in relation to GDP, even if industrial energy intensity remained unchanged.

1 B. Jenness, M. Haney and A. Storey. *Energy Efficiency Indicators: Conceptual Framework and Data Sources*. Prepared by Informetrica Limited for Natural Resources Canada, March 31, 1995.

The development of the formulas for the indexes in the following sections is based on the following "identity":

$$E = A\frac{E}{A} = A\Omega$$

where E is energy use, and A is the level of activity. The quantity Ω is the intensity of energy use per unit of activity.

The following section develops indexes that characterize different influences on the movements in aggregate energy use. For an energy-consuming sector composed of several subsectors (or "outlets"), movements in aggregate energy can be due to changes in the mix of activity of its subsectors or changes in the intensity of energy use of its subsectors. The relationship between aggregate energy use in a sector and those of its subsectors is:

$$E = \sum_i E_i = \sum_i A_i \Omega_i$$

where the subscript "i" denotes the "ith" subsector.

We are interested in separating aggregate activity effects from activity mix effects between subsectors. Accordingly, we rewrite the above equation as:

$$E = A \sum_i a_i \Omega_i$$

where "a_i" is the activity share of the "ith" subsector:

$$a_i = \frac{A_i}{A}$$

Our basic energy identity is then:

$$E = A \sum_i a_i \Omega_i$$

Since we will be developing formulas for indexes, a notation is needed to denote time. The convention used in the following sections is to subscript a quantity with "o" to denote the base-period value. The absence of an "o" subscript will always denote the current time period. Thus, for example, the above identity in index form becomes:

$$\frac{E}{E_o} = \frac{A \sum_i a_i \Omega_i}{A_o \sum_i a_{io} \Omega_{io}}$$

Factorization of Energy into Activity and Average Intensity

We first note that the energy index is the product of the activity and average intensity indexes:

$$\frac{E}{E_o} = \frac{A}{A_o}\frac{\Omega}{\Omega_o}$$

Next we note that for any two quantities x and y we have:

$$xy-1 = (x-1) + (y-1) + (x-1)(y-1)$$

This identity is useful when "x" and "y" are indexes because it states that if an index is the product of two other indexes, the *change* in the index is the sum of the changes of the two indexes plus an interaction term, which is the product of changes in the two indexes. (This identity will be used at several points in the following development when we need to factor the product of two indexes.)

This identity allows us to factor the change in the energy index into a total activity component, an average intensity component and an interaction term:

$$\frac{E}{E_o}-1 = (\frac{A}{A_o}-1) + (\frac{\Omega}{\Omega_o}-1) + (\frac{A}{A_o}-1)(\frac{\Omega}{\Omega_o}-1)$$

For brevity, we designate the interaction term as "ε."

The Structure and Intensity Indexes

The average intensity index is defined in terms of its subsector activity shares and intensities as follows:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_i \Omega_i}{\sum_i a_{io} \Omega_{io}}$$

Represented this way, we see that movements in the average sector intensity consists of movement in activity shares and in the intensities of the subsectors. To isolate these effects, we define two other indexes. Each index uses the same formula as above, but holds one of the quantities fixed at base-period values.

We define the ("pure") structure index as:

$$\frac{S}{S_o} = \frac{\sum_i a_i \Omega_{io}}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' intensities remained fixed at base-period values.

Similarly, we define the ("pure") intensity index as:

$$\frac{I}{I_o} = \frac{\sum_i a_{io} \Omega_i}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' activity shares remained fixed at base-period values.

The Base-Weighted Form of the Indexes

Before introducing the factorization of the average intensity into its structure and "pure" intensity components, it is useful to note that the structure and intensity indexes have a simple representation as the base-period, energy-weighted sum of simple indexes.

We note that the structure index can be represented as follows:

$$\frac{S}{S_o} = \frac{\sum_i a_{io} \Omega_{io} \frac{a_i}{a_{io}}}{\sum_i a_{io} \Omega_{io}}$$

We also note that:

$$\frac{a_{io} \Omega_{io}}{\sum_i a_{io} \Omega_{io}} = \frac{E_{io}/A_o}{E_o/A_o} = \frac{E_{io}}{E_o} = b_i$$

Where "b_i" is the base-period energy share of the "ith" subsector. (Note that we will not use the "o" subscript for bi — this notation will always refer to the base-period energy share.) This yields the following representation of the structure index:

$$\frac{S}{S_o} = \sum_i b_i \frac{a_i}{a_{io}}$$

That is, the structure index is the base-period, energy-share weighted sum of the subsector activity share indexes.

In exactly the same way, we derive the following representation for the intensity index:

$$\frac{I}{I_o} = \sum_i b_i \frac{\Omega_i}{\Omega_{io}}$$

So the "pure" intensity index for the sector is simply the base-period, energy-share weighted sum of the subsector *average* intensity indexes. (Note the emphasis, "pure" intensity index is *not* the weighted sum of subsector "pure" intensity indexes. We will denote the "pure" intensity index with the Roman letter "I" and average intensities with the Greek letter Ω.)

Finally, we note that since the base-period weights sum to unity, the above two formulas also hold in index-change form. In particular:

$$\frac{S}{S_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} - 1\right) \quad \text{and} \quad \frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1\right)$$

Factorization of Intensity into Structure and "Pure" Intensity

We return to the average intensity index and demonstrate its relationship to the structure and "pure" intensity indexes. Using the same device as in the previous section:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_i \Omega_i}{\sum_i a_{io} \Omega_{io}} = \frac{\sum_i a_i \Omega_{io} \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}}{\sum_i a_{io} \Omega_{io}} = \sum_i b_i \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}$$

Since the base-period energy shares sum to unity, the above can be written in change form as:

$$\frac{\Omega}{\Omega_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}} - 1\right)$$

Observe that the quantity in parentheses is the change in the product of two indexes, so it can be factored (as with the total energy index) as follows:

$$\frac{\Omega}{\Omega_o}-1=\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)+\sum_i b_i\left(\frac{\Omega_i}{\Omega_{io}}-1\right)+\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)\left(\frac{\Omega_i}{\Omega_{io}}-1\right)$$

This demonstrates the relationship sought: the first sum is the structure index and the second is the "pure" intensity index. The third term — which is a sum of "interaction terms" — will be denoted by "δ." So *changes* in the average intensity index are related to the two other indexes as follows:

$$\frac{\Omega}{\Omega_o}-1=\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta$$

Note that this completes our factorization of the total energy index:

$$\frac{E}{E_o}-1=\left(\frac{A}{A_o}-1\right)+\left(\frac{\Omega}{\Omega_o}-1\right)+\varepsilon=\left(\frac{A}{A_o}-1\right)+\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta+\varepsilon$$

where, as before, ε is the intensity-activity interaction term and δ is the structure-intensity interaction term.

In anticipation of needs in the next section, we introduce some notation here concerning the interaction term ε. First recall that from the definition of ε (and the factorization formula) for average intensity we have:

$$\varepsilon=\left(\frac{A}{A_o}-1\right)\left(\frac{\Omega}{\Omega_o}-1\right)=\left(\frac{A}{A_o}-1\right)\left[\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta\right]$$

so ε can be represented as the sum of three "interaction terms":

$$\varepsilon_1=\left(\frac{A}{A_o}-1\right)\left(\frac{S}{S_o}-1\right)=\left(\frac{A}{A_o}-1\right)\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)$$

$$\varepsilon_2=\left(\frac{A}{A_o}-1\right)\left(\frac{I}{I_o}-1\right)=\left(\frac{A}{A_o}-1\right)\sum_i b_i\left(\frac{\Omega_i}{\Omega_{io}}-1\right)$$

$$\varepsilon_3=\left(\frac{A}{A_o}-1\right)\delta=\left(\frac{A}{A_o}-1\right)\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)\left(\frac{\Omega_i}{\Omega_{io}}-1\right)$$

These three terms will be used in the development of the next section.

Two-Way Factorization of Total Energy

The factorization of a sector's energy index into activity, structure and intensity indexes (with attendant interaction terms) provides measures that summarize different influences on the movements of the total energy index. However, the individual contributions of the subsectors to each of these indexes is also of interest. For example, if we observe movements in the intensity index, it is useful to know which subsectors are contributing to the movement and in which direction. This is true even if there are no movements in the aggregate index, since this may be due to offsetting contributions of the subsectors.

The subsector composition of the change in the aggregate indexes can also reveal useful patterns both between subsectors and between aggregate indexes. For example, it may reveal that one set of subsectors is moving the aggregate energy index via the structure and activity indexes, while a different set of subsectors is moving the energy index via the intensity index.

These considerations motivate the development of the "two-way" decomposition formulas described in this section.

We first note that:

$$\frac{E}{E_o} = \sum_i \frac{E_{io}}{E_o} \frac{E_i}{E_{io}} = \sum_i b_i \frac{E_i}{E_{io}}$$

or in index change form:

$$\frac{E}{E_o} - 1 = \sum_i b_i \left(\frac{E_i}{E_{io}} - 1 \right)$$

Thus an individual subsector's (total) contribution to the change in the sector's total energy index is simply the change in its own energy index times its base-period energy share.

We note that the change in the subsectors energy index can be represented as follows:

$$\frac{E}{E_{io}} - 1 = \frac{A}{A_o} \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}} - 1$$

Factoring the product twice yields:

$$\frac{E}{E_{io}}-1=(\frac{A}{A_o}-1)+(\frac{a_i}{a_{io}}-1)+(\frac{\Omega_i}{\Omega_{io}}-1)+(\frac{a_i}{a_{io}}-1)(\frac{\Omega_i}{\Omega_{io}}-1)+(\frac{A}{A_o}-1)(\frac{a_i}{a_{io}}-1)+(\frac{A}{A_o}-1)(\frac{\Omega_i}{\Omega_{io}}-1)+(\frac{A}{A_o}-1)(\frac{a_i}{a_{io}}-1)(\frac{\Omega_i}{\Omega_{io}}-1)$$

Multiplying this equation through by b_i and summing over i we see that each of the sums on the right-hand side add to, respectively, the change in the total sector activity index, the change in the structure index, the change in the "pure" intensity index, δ, ε_1, ε_2, and ε_3.

This completes the two-way factorization of the changes in the total energy index. The factorization yields values for the following table:

	Total Energy	Activity	Structure	Intensity	Interaction Terms
Sector total					
Contributions of:					
subsector 1					
subsector 2					
. . .					
subsector n					

This schematic represents the analytical framework used for studying movements in the various aggregate indexes at a given level of the "pyramid." Interesting observations in any subsector row of the table were pursued by "drilling down" to the next level of the pyramid.

Adjustments for Weather

Since weather can exert a large influence on the intensity of energy use, the "pure" intensity index suffers the defect that it includes weather effects. This section extends the factorization to include weather adjustments. These adjustments are applicable in the residential and commercial sectors for activities related to space heating and space cooling.

The weather adjustment takes the form:

$$\Omega = w\Omega'$$

where "w" is the weather adjustment and Ω' is weather-adjusted intensity. For space heating and space cooling activities, an estimate of "w" is available directly in the form of a degree-day elasticity. However, for aggregate sectors that span subsectors with different weather adjustments or have only some subsectors subject to adjustment, the sector's total weather adjustment must be computed implicitly as:

$$w = \frac{\sum_i a_i \Omega_i}{\sum_i a_i \Omega'_i}$$

Using this notation, we incorporate the weather adjustment in our "pure" intensity index:

$$\frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1\right) = \sum_i b_i \left(\frac{w_i \Omega'_i}{w_{io} \Omega'_{io}}\right)$$

Factoring the term in parentheses yields:

$$\frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{w_i}{w_{io}} - 1\right) + \sum_i b_i \left(\frac{\Omega'_i}{\Omega'_{io}} - 1\right) + \sum_i b_i \left(\frac{w_i}{w_{io}} - 1\right)\left(\frac{\Omega'_i}{\Omega'_{io}} - 1\right)$$

This expresses the changes in the "pure" intensity index as the sum of the changes in a "pure" weather index, a "pure" weather-adjusted intensity index and a new interaction term. We will use the notation W for the "pure" weather index, I' for the pure weather-adjusted intensity index and λ for the weather-intensity interaction term. Our factorization of changes in the total energy index (for sectors subject to weather adjustment) is now:

$$\frac{E}{E_o} - 1 = \left(\frac{A}{A_o} - 1\right) + \left(\frac{S}{S_o} - 1\right) + \left(\frac{W}{W_o} - 1\right) + \left(\frac{I'}{I'_o} - 1\right) + \lambda + \delta + \varepsilon$$

The two new indexes can be interpreted in the same way as the other "pure" indexes. That is, the weather index measures what the energy index would have been had all factors but weather adjustment remained at base-period values, and the weather-adjusted index measures what it would have been had all factors but weather-adjusted intensities remained at base-period values.

Decomposition Applied to the Total Economy

The four sectors comprising energy use for the total economy lack a sensible common activity measure. So the decomposition of the total energy index into a total activity index, total structure index, etc., is problematic. However, recall that the changes in the energy index can be represented as:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{E}{E_{io}}-1\right)$$

(where "bi," as before, denotes the sectors base-period energy share) and that for each of the four sectors, we have decomposed the changes in their energy indexes as:

$$\frac{E_i}{E_{io}}-1=\left(\frac{A_i}{A_{io}}-1\right)+\left(\frac{S_i}{S_{io}}-1\right)+\left(\frac{W_i}{W_{io}}-1\right)+\left(\frac{I'_i}{I'_{io}}-1\right)+\lambda_i+\delta_i+\varepsilon_i$$

so the changes in the total economy energy index can be written:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{A_i}{A_{io}}-1\right)+\sum_i b_i\left(\frac{S_i}{S_{io}}-1\right)+\sum_i b_i\left(\frac{W_i}{W_{io}}-1\right)+\sum_i b_i\left(\frac{I'_i}{I'_{io}}-1\right)+\sum_i b_i\lambda_i+\sum_i b_i\delta_i+\sum_i b_i\varepsilon_i$$

We use this formula to attribute changes in the total economy energy index to "generic" activity, structure, weather, weather-adjusted intensity and interaction effects.

Note on Interaction Terms

Recall that early in this development, the following identity was introduced:

$$xy-1=(x-1)+(y-1)+(x-1)(y-1)$$

As stated, this identity is useful when studying an index that is the product of two other indexes, since it "factors" the changes in the product into the changes of the two indexes plus an interaction term. It is this identity on which the quality of our "factorization" rests. When the changes in "x" and "y" are "modest," this identity lets us ignore the interaction term, and we can focus on the behaviour of the two component indexes. As an example, the two component indexes can change by 10% and the interaction term will be only 1%. So, in this case we are not far wrong in ignoring the interaction term and saying that the product of the two indexes has changed by 20% of which 10% comes from "x" and another 10% from "y."

The direction of the error in the approximation depends on the direction of change in the component indexes. If the component indexes either both increase or both decrease, the interaction term is always positive, so the sum of the changes in the component indexes is an underestimate of the total change. If the component indexes differ in the direction of their changes, then the interaction term is always negative, so the sum of the changes overshoots the total change.

We can comfortably ignore the interaction term ε, which is the product of the changes in the total activity index and the average intensity index — both of which we have reason to expect will change only modestly. However, we cannot be sanguine about the δ and λ interaction terms since they are the *sum* of interaction terms across all subsectors. Even if there are reasons to believe that subsector interaction contributions are small, we must not neglect the fact that we are "adding them up." The interaction term δ deserves special consideration because one of the component indexes is the activity *share* index. Thus, we must be cautious in looking at components of d when we expect that a subsector may have gained considerable activity share. A subsector that changes its activity share from 5% to 10% (or 1% to 2%) has an activity share index change of 100%, which stretches the notion of "modest." This condition is moderated somewhat by the fact that the contribution of the subsector to δ is weighted by its base-period energy share. That is, its contribution to the total interaction term will only be large if it has a large base-period energy share.

Decomposition Applied to End-Use Sectors

Total secondary energy consumed in the economy is the sum of the secondary energy consumed by each of the end-use sectors, as defined by Natural Resources Canada (see Appendix C):

1) industrial
2) transportation
3) residential
4) commercial (including public administration)
5) agriculture

The factorization methodology provides a basis for distinguishing between activity, structure and intensity factors, but the activity measure appropriate for any particular sector may not be applicable to another. The following activity measures are used for each sector:
Industrial–GDP originating from the sector
Transportation–passenger-kilometres and freight tonne-kilometres
Residential–number of households
Commercial (including public administration)–floor space

Industrial Sector

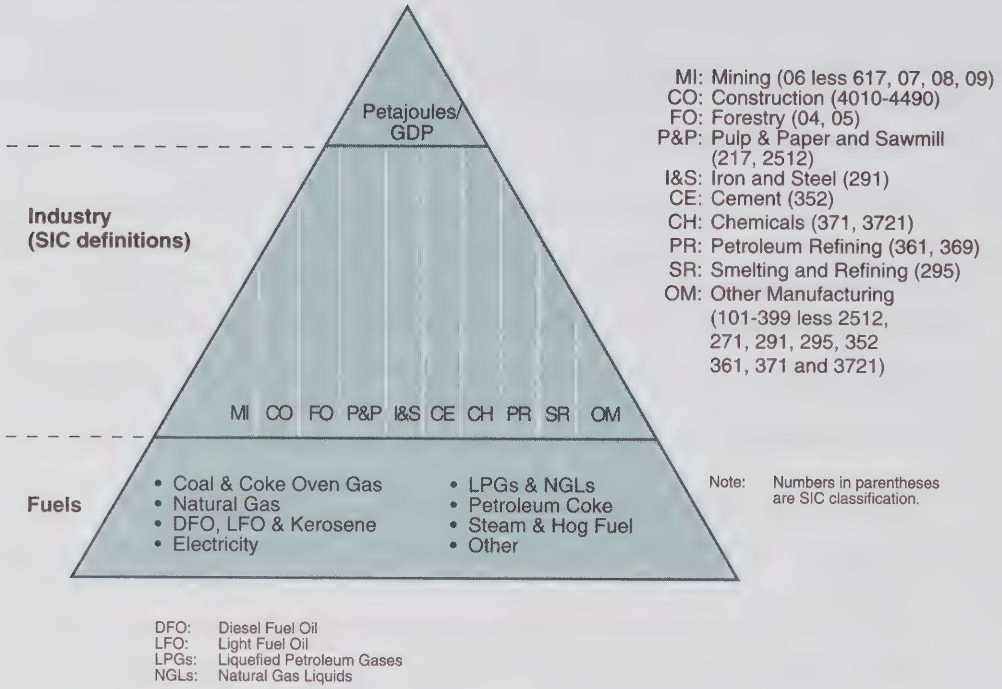
The industrial decomposition is based on energy consumption per unit of industrial output (GDP) for 10 subaggregates in the mining (1), construction (1), forestry (1) and manufacturing (7) subsectors.

Secondary end-use energy information is produced by Natural Resources Canada for use in its industrial sector energy end-use models. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for hog fuel and pulping liquor consumption and producer's consumption of refined petroleum products, as well as some historical revisions mainly pertaining to natural gas and butane consumption by the chemical, mining and other manufacturing industries.

Industrial output data for the 10 subsectors are aggregations of GDP by industry (at 1986 prices) data produced by Statistics Canada, published in *Gross Domestic Product by Industry* (15-001). Statistics Canada uses a Standard Industrial Classification system to identify industries; the combinations used in this analysis are identified on the industrial sector indicator pyramid. It should be noted that industry GDP disaggregated by fuel type is not available from Statistics Canada. Instead, estimates were constructed using shares of output energy demand.

As shown on the indicator pyramid (Figure B.1), the factorization of energy use for the industrial sector involves three levels. Level 1 (at the bottom) defines the sectoral influences at the most detailed level by fuel type. Levels 2 captures the influence of shifting industrial composition. Aggregating over the products of these factors yields the third level, the change in aggregate industrial secondary end-use attributable to each of the three components (activity, structure and intensity) in petajoules per unit of output.

Figure B.1 Industrial Sector Indicator Pyramid



Transportation Sector

The structure for analysing transportation is based on a division of transportation activity into two parts: passenger and freight.

Passenger Transport

The passenger transport decomposition is based on energy consumption per passenger-kilometre for seven modal subaggregates in the road (3), bus (3), rail (1) and air (1) subsectors.

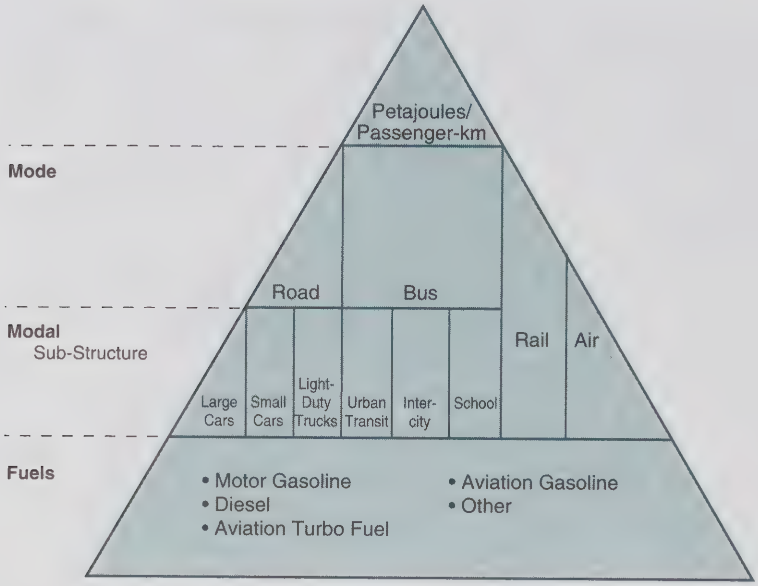
Secondary end-use energy information is produced by Natural Resources Canada for use in its transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and aviation fuel, public administration use of aviation fuels and some historical revisions.

Passenger-kilometre data are drawn from a number of sources:

- **Road Data** are based on the change in the average population per vehicle benchmarked in 1990 to the average number of passengers per car reported in the *Royal Commission on Passenger Transportation*, Volume 2, multiplied by the distance cars travel. The same average number of passengers per car benchmark is used for both large and small cars. Trucks are defined as light trucks, excluding those used for commercial purposes.
- **Bus Data** are defined as the product of total distance buses travelled and average bus occupancy levels. Average bus occupancies are benchmarked in 1990 to the bus seat capacity and occupancy ratios of the *Royal Commission on Passenger Transportation*, Volume 2. Variations in bus occupancy levels are approximated based on the index of the ratio of total passengers to total distance travelled and an index of average trip distance. Total passengers and distance travelled data series are drawn from Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215), while the average trip distance data originates from the Commission de Transport de la Communauté de Montréal.
- **Rail Data** are reported in Statistics Canada's *Rail in Canada* (52-216).
- **Air Data** are drawn from Natural Resources Canada's database, which is based on Statistics Canada's airline traffic statistics.

As shown on the indicator pyramid (Figure B.2), the factorization of energy use for the passenger transport sector involves four levels. In this instance, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.2 Passenger Transport Indicator Pyramid



Freight Transport

The freight transport decomposition is based on energy consumption per freight tonne-kilometre for five modal subaggregates in the truck (3), rail (1) and marine (1) subsectors.

Secondary end-use energy information is produced by Natural Resources Canada for use in its transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all uses of motor gasoline, commercial and other institutional use of diesel fuel oil and some historical revisions. End-use energy demand by medium/heavy and extra heavy trucks was scaled down by the amounts reported for bus passenger transport.

Freight tonne-kilometre data are drawn from a number of sources:

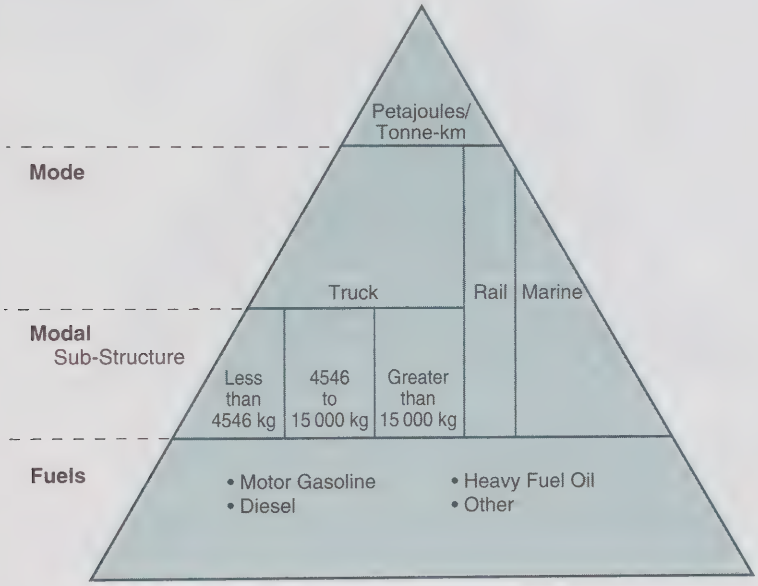
- **Truck Data** were drawn from Statistics Canada's *Trucking in Canada* (53-222) and Transport Canada's *Transportation in Canada* (Annual Report) for the heavy truck categories. A fixed tonnage of 500 kilograms and 1500 kilograms per kilometre has been assigned to the light and medium size trucks categories as they pertain mainly to service trucking rather than freight. Light trucks are defined as excluding those used for personal use. Tonne-kilometres were attributed by fuel type based on input fuel consumption.

- **Rail Data** were drawn from Statistics Canada's *Rail in Canada* (52-216).

- **Marine Data** were drawn from Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

As shown on the indicator pyramid (Figure B.3), the factorization of energy use for the freight transport sector involves four levels. Once again, levels 2 and 3 capture the influence of shifting modal structure.

Figure B.3 Freight Transport Indicator Pyramid



Residential Sector

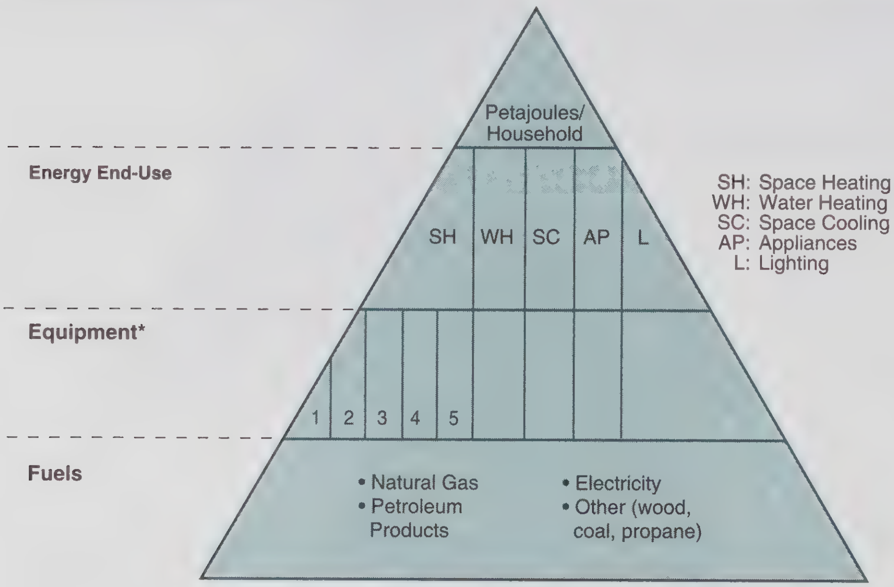
The residential decomposition is based on energy consumption per household.

Secondary end-use energy information is produced by Natural Resources Canada for use in its residential sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with some historical revisions.

Household data are also produced by Natural Resources Canada and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division and Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.4), the factorization of energy use for the residential sector involves four levels. For this sector, levels 2 and 3 measure the impact of shifting appliance choice.

Figure B.4 Residential Sector Indicator Pyramid



*Equipment examples include:
Space heating – normal, mid- and high-efficiency furnaces, electric baseboard heaters, heat pumps, coal, wood & propane furnaces and dual systems
Space cooling – room air conditioner and central air conditioner
Appliances – refrigerator, freezer, clothes washer, electric and gas dryer, electric and gas ranges, dishwasher, etc.

Commercial Sector

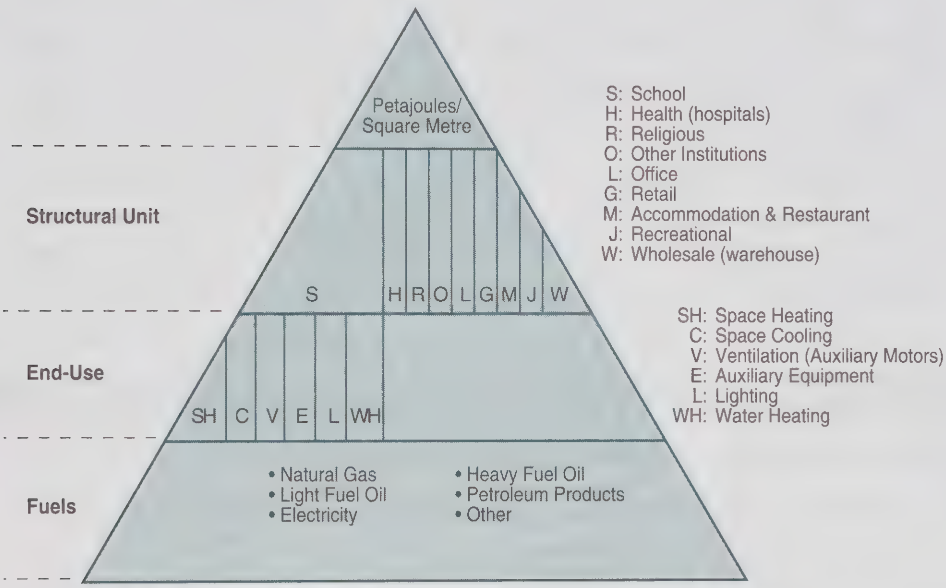
The commercial decomposition is based on energy consumption per square metre of floor space for nine building types.

Secondary end-use energy information is produced by Natural Resources Canada for use in its commercial sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with diesel fuel oil use re-allocated to the transportation sector and with some historical revisions. Electricity for street lighting, as published by Statistics Canada *Electric Power Statistics* (57-202), was netted out of the factorization.

Floor space data are produced by Informetrica Limited for Natural Resources Canada and are based on investment and capital stock data produced by Statistics Canada, Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.5), the factorization of energy use for the commercial sector involves four levels. For this sector, level 2 captures appliance mix effects, while level 3 captures the influence of building types.

Figure B.5 Commercial Sector Indicator Pyramid



Reconciliation of Data on Energy Use Found in this Report with Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* Data – 1996

1 Introduction

The bulk of the energy use data presented in this report is taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* (QRESD). However, for the purpose of the analysis undertaken in this study, some sectoral re-allocations of the original Statistics Canada data was required. These adjustments are documented in Table C.1 on page __.

While our preference would have been to use QRESD data as is, some of the sectoral allocations in the QRESD were judged not to be adequate for energy end-use analysis. For example, Statistics Canada's definition of the commercial sector includes the use of aviation fuel by the public sector. Natural Resources Canada's end-use analytical framework for the commercial sector estimates building energy use. Using unmodified QRESD sector definitions would have led to the inclusion of aviation fuels in the commercial sector and their allocation to one of the building types defined in Natural Resources Canada's commercial end-use database.

The following describes modifications to QRESD sector definitions in each end-use sector for the purpose of this report.

2 Residential Sector

One modification was made to the QRESD definition of the residential sector: the addition of fuel wood use.

The inclusion of fuel wood use is a net addition to residential energy demand as reported in the QRESD. Residential fuel wood use is estimated using Natural Resources Canada's Residential End-Use Model.

3 Agriculture Sector

No modification.

4 Commercial Sector

Two modifications were made to the QRESD definition of the commercial sector: the re-allocation of commercial motive fuels to the transportation sector and the re-allocation of commercial butane demand to the chemical sector.

The re-allocation of commercial motive fuels is done in order to include only stationary energy use in the commercial sector. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

The re-allocation of butane demand from commercial to chemical demand is due to a misallocation of butane consumption in the QRESD. From 1993 until now, a significant quantity of butane was reported as commercial and other institutional demand. The matter has been investigated by Statistics Canada and Natural Resources Canada. Corrected commercial butane demand is negligible, and butane demand reported as commercial and other institutional was re-allocated to chemical energy use.

Also, although it does not affect total commercial electricity demand, street lighting electricity consumption is now identified separately as reported by Statistics Canada's *Electric Power Statistics* (#57–202).

5 Industrial Sector

Three types of modifications were done to the QRESD definition of the industrial sector: two re-allocations of energy demand to another sector, a net addition of energy demand and a data revision.

The first re-allocation relates to butane demand misallocated by Statistics Canada since 1993 as commercial and other institutional. In this report, this energy use has been re-allocated to the chemical sector.

The second re-allocation relates to producer consumption by the refining industry. Statistics Canada classifies the use of non-purchased petroleum products by the petroleum refining industry as producer consumption. In this report, this energy use has been re-allocated to the industrial sector (petroleum refining industry) as it is an end-use consumption.

The net addition to energy use relates to solid wood waste and spent pulping liquor. Data on consumption of solid wood waste and spent pulping liquor is included in a supplementary table in the QRESD but not in the QRESD's energy supply-demand balance. For the purpose of this report, the energy demand of the industrial sector is modified to include solid wood waste and spent pulping liquor consumption.

The data revision pertains to the breakdown of natural gas demand by the chemical industry between fuel and feedstock, where Statistics Canada has provided a revised and more complete breakdown for the period.

Details and the relation to the QRESD regarding these re-allocations, additions and revisions are described in Table C.1.

6 Transportation Sector

Two modifications were made to the QRESD definition of the transportation sector: the re-allocation of commercial motive fuels from the commercial sector and the re-allocation of pipeline fuel use to producer consumption.

The re-allocation of commercial motive fuels from the commercial sector to the transportation sector is the mirror adjustment to that described above for the commercial sector.

The re-allocation of pipeline fuel use to producer consumption is done in order to include only vehicle energy use in the transportation sector. Since pipeline fuel is fuel used in the distribution of energy to end-use markets, we have re-allocated it to producer consumption and do not consider it end-use consumption. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

Table C.1
Reconciliation of Data on Energy Use Found in this Report with Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* – 1996

SECTOR	QRESD Data	Fuel Wood	Commercial Diesel	Commercial & Public Admin. Aviation Fuels	Commercial & Public Admin. Motor Gasoline	Re-allocation of Commercial Butane	Revision of Chemical Non-Energy Use Natural Gas	Pipeline Fuels	Solid Wood Waste & Pulping Liquor	Re-allocation of Producer Consumption by Refining Industry	Energy Efficiency Trends Data
Residential	1362	91									1453
Agriculture	224										224
Commercial	1166		(70)	(29)	(54)	(13)					1000
Transportation	2130		70	29	54			(254)			2029
Industrial	2249					13	(33)		454	244	2926
Final Demand	7131	91	0	0	0	0	(33)	(254)	454	244	7632
Non Energy	845						33				878
Producer Consumption	1006							254		(244)	1016
Net Supply	8982	91	0	0	0	0	0	0	454	0	9526
Conversion Losses*	1468										1468
Total Primary	10449	91	0	0	0	0	0	0	454	0	10994

Notes on sources of enery use data for five end-use sectors:

RESIDENTIAL:
Base data taken from revised QRESD (in 1996 issue of QRESD, Table 1B, line 43) plus fuel wood use (estimated from NRCan's Residential End-Use Model).

AGRICULTURE:
Base data taken from revised QRESD (in 1996 issue of QRESD, Table 1B, line 42)

COMMERCIAL:
Base data taken from revised QRESD (in 1996 issue of QRESD, Table 1B, line 44 plus line 45) less commercial and public administration motor gasoline (in 1996 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) less commercial diesel (in 1996 issue of QRESD, Table 1D, diesel column, line 45) less commercial and public administration aviation gasoline (in 1996 issue of QRESD, Table 1D, aviation gasoline column, line 44 plus line 45) less commercial and public administration aviation turbo fuel (in 1996 issue of QRESD, Table 1D, aviation turbo fuel column, line 44 plus line 45) less commercial butane (in 1996 issue of QRESD, Table 16, Canada butane column, line 45)

TRANSPORTATION:
Base data taken from revised QRESD (in 1996 issue of QRESD, Table 1B, line 41) less pipeline fuels (in 1996 issue of QRESD, Table 1B, natural gas plus electricity plus petroleum products columns, line 38) plus commercial and public administration motor gasoline (in 1996 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) plus commercial diesel (in 1996 issue of QRESD, Table 1D, diesel column, line 45) plus commercial and public administration aviation gasoline (in 1996 issue of QRESD, Table 1D, aviation gasoline column, line 44 plus line 45) plus commercial and public administration aviation turbo fuel (in 1996 issue of QRESD, Table 1D, aviation turbo fuel column, line 44 plus line 45)

INDUSTRIAL:
Base data taken from revised QRESD (in 1996 issue of QRESD, Table 1B, line 30) plus solid wood waste and pulping liquor (in 1996 issue of QRESD, Table 19) plus producer consumption by refinery industry of still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG (in 1996 issue of QRESD, Table 1D, still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG columns, line 15) plus commercial butane (in 1996 issue of QRESD, Table 16, Canada butane column, line 45) less natural gas non-energy use re-allocation (in 1996 issue of QRESD, Table 20, non-energy use line, other provinces column).

* Electricity conversion rates: Hydro-electricity converted at rate of 3.6 megajoules per kilowatt-hour; nuclear electricity converted at rate of 11.564 megajoules per kilowatt-hour.

Reconciliation of Definition on Estimated Carbon Dioxide Emissions Found in this Report with Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995*

1 Introduction

The greenhouse gas, particularly the carbon dioxide emissions, data presented in this report are estimated using emissions factors developed by Environment Canada (EC). The emissions estimates provided herein mirror the estimates presented in *Trends in Canada's Greenhouse Gas Emissions 1990 to 1995 (TCGGE90-95)*, since both Natural Resources Canada (NRCan) and EC use the energy demand data from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD) as a base. However, the two organizations use different sectoral mapping.

EC prepares its emissions inventory according to the specifications of the Intergovernmental Panel on Climate Change. NRCan has developed a mapping that is most suited to energy end-use analysis. The objective of this appendix is to help readers understand the similarities and differences between TCGGE90-95 and NRCan sectoral emissions estimates for the five end-use sectors covered in this report. The comparison is presented for the year 1996 for illustrative purposes.

2 Residential Sector

There is one difference between NRCan and TCGGE90-95 residential emissions definitions. NRCan residential emissions include end-use electricity-related emissions, which are reported under power generation in TCGGE90-95.

3 Agriculture Sector

For the agriculture sector, TCGGE90-95 reclassifies all farm diesel and motor gasoline in the transport sector, while NRCan leaves this consumption in the agriculture sector as is done in the QRESD.

NRCan agricultural emissions also include end-use electricity-related emissions, which are reported under power generation in TCGGE90-95.

4 Commercial Sector

There are three differences between the NRCan and TCGGE90-95 definitions of commercial emissions:

First, there is a re-allocation of commercial sector butane consumption to the chemical sector to correct for a misallocation of butane in the QRESD.

Second, there is a re-allocation of public administration diesel consumption in TCGGE90-95 from the commercial sector to the transportation sector.

Third, NRCan commercial emissions include end-use electricity-related emissions, which are reported under power generation in TCGGE90-95.

5 Industrial Sector

For the industrial sector, there are four differences between the sectoral definitions of TCGGE90-95 and NRCan:

First, there is a re-allocation in TCGGE90-95 of industrial diesel fuel use from the industrial sector to the transportation sector.

Second, there is NRCan's re-allocation of producer consumption of petroleum products by the petroleum refining industry from the producer consumption sector to petroleum refining within the industrial sector.

Third, there is a re-allocation of commercial sector butane consumption to the chemical sector to correct for a misallocation of butane in the QRESD.

Fourth, NRCan industrial emissions include end-use electricity-related emissions, which are reported under power generation in TCGGE90-95.

6 Transportation Sector

All of the differences to the boundary of the transportation sector between NRCan and TCGGE90-95 are related to re-allocation or exclusion of QRESD data in TCGGE90-95 from its inventory and allocation by NRCan of end-use electricity-related emissions to the end-use sectors.

First, there is the re-allocation to the transportation sector of public administration diesel consumption, industrial diesel, and farm diesel and motor gasoline.

Second, there is the exclusion from EC's inventory of emissions resulting from the use of energy in the foreign marine and foreign aviation subsectors.

Third, NRCan transportation emissions include end-use electricity-related emissions, which are reported under power generation in TCGGE90-95.

Table D1
Reconciliation of 1996 Estimates of Carbon Dioxide Emissions Found in this Report with Definitions in *Trends in Canada's Greenhouse Gas Emissions 1990-1995*

(megatonnes)

SECTOR	Energy Efficiency Trends in Canada Data	Public Admin. Diesel	Commercial Butane	Industrial Diesel	Farm Diesel	Farm Motor Gasoline	Foreign Aviation***	Foreign Marine***	Producer Consumption by Refining Industry	End-Use Electricity Related	Estimated Emissions Based on TCGGE90-95 Definitions
Residential	71.2									(24.2)	47.0
Agriculture	14.3				(6.8)	(3.0)				(1.8)	2.8
Commercial	51.6	(1.5)	0.8							(20.9)	30.0
Transportation	139.9	1.5		9.2	6.8	3.0	(3.1)	(2.1)		(0.1)	155.0
Industrial*	138.8		(0.8)	(9.2)					(14.5)	(36.5)	77.8
Final Demand	*415.9*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*(3.1)*	*(2.1)*	*(14.5)*	*(83.5)*	*312.6*
Conversion Losses	15.8									83.5	99.3
Producer Consumption	41.4								14.5		55.9
Industrial Processes and Non-Energy Related**	42										42
Total Emissions	515	0.0	0.0	0.0	0.0	0.0	(3.1)	(2.1)	0.0		510

Note: Subtract numbers in brackets when adding across rows to arrive at the total shown in the right-hand column.

* Industrial emissions are estimated using Statistics Canada revised natural gas fuel and feedstock consumption figures for the chemical industry. Should it not be accounted for, estimated industrial emissions would be 1.3 megatonnes higher and non-energy emissions reduced accordingly.

** As a proxi for 1996, "Industrial Processes and Non-Energy Related" was set to be four percent over its 1995 reported value in Trends in Canada's Greenhouse Gas Emissions 1990-1995 adjusted for Statistics Canada revised natural gas fuel and feedstock consumption figures for the chemical industry. Estimation includes fluxes in agricultural soils and incineration of municipal waste.

*** As required by International Reporting Guidelines, Canada's official National Inventory excludes emissions associated with Foreign Aviation and Foreign Marine. Exluding these emissions from *Energy Efficiency Trends in Canada* would result in total emissions equivalent to that estimated for Canada's official National Inventory.

Greenhouse Gas Emissions Trends Analysis

The analysis of emissions from the use of energy to meet end-use requirements, which is presented in this report, can be summarized by the following three equations:

First, $$CO_{2\ sec} = CO_{2\ res} + CO_{2\ com} + CO_{2\ ind} + CO_{2\ tran} + CO_{2\ agr} \quad (1)$$

where $CO_{2\ sec}$: carbon dioxide emissions from secondary energy use

$CO_{2\ res}$: carbon dioxide emissions from residential energy use

$CO_{2\ com}$: carbon dioxide emissions from commercial energy use

$CO_{2\ ind}$: carbon dioxide emissions from industrial energy use

$CO_{2\ tran}$: carbon dioxide emissions from transportation energy use

$CO_{2\ agr}$: carbon dioxide emissions from agriculture energy use

The elements of equation 1 were presented in Chapter 2, which provides an overview of trends in emissions and energy use at the aggregate secondary level.

In each energy-consuming sector, energy-related emissions are the product of energy use and the carbon dioxide intensity of this energy use. This is written as:

$$CO_2 = E \times (CO_2/E) \quad (2)$$

where CO_2: Carbon dioxide emissions

E: Energy use

CO_2/E: Carbon dioxide intensity of energy use

The change (expressed as Δ in the equation below) in carbon dioxide emissions is approximated by the sum of growth in energy use and carbon intensity:

$$\Delta\, CO_2 = \Delta\, E + \Delta\, (CO_2/E) \quad (3)$$

The change in carbon dioxide emissions is approximated by the sum of growth in energy use and carbon intensity. The analysis of emissions presented in chapters 3 to 7, which cover the five end-use sectors, respectively, elaborates on the principal factors underlying growth in both energy use and carbon dioxide intensity of energy use, thereby documenting the forces driving growth in energy-related carbon dioxide emissions. The only difference between the sum of factors on the right-hand side of equation (2) and the total growth in CO_2 will be the product of the growth in E and CO_2, i.e., ($\Delta E \times \Delta CO_2$). This amount, and hence the difference between both sides of the equation, will vary in size as a function of the size of both ΔE and ΔCO_2.

Glossary of Terms

The glossary is divided into six sections: General, Residential Sector, Commercial Sector, Industrial Sector, Transportation Sector and Agricultural Sector. The General section includes general terminology as well as terminology common to more than one sector.

General

Activity: Term used to characterize major drivers of energy use in a sector (e.g., number of households in the residential sector).

Building Envelope: The materials and surfaces in the building shell, including walls, ceilings, roof, basement walls, windows and doors.

Calibration Process: Process by which deviation between disaggregated and aggregated data are determined and rectified.

Canada's National Action Program on Climate Change (NAPCC): Sets strategic directions in pursuit of Canada's commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000 and provides guidance for actions beyond the year 2000. The NAPCC pursues sectoral and broad-based opportunities through the development of appropriate actions and measures by private and public jurisdictions, reviews progress, and makes adjustments as required.

Carbon Dioxide: A compound of carbon and oxygen formed whenever carbon is burned. Chemical formula: CO_2. Carbon dioxide is a colourless gas that absorbs infrared radiation mostly at wavelengths between 12 and 18 microns; it behaves as a one-way filter allowing incoming, visible light to pass through in one direction while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus, it acts as a greenhouse and has the potential to increase the surface temperature of the earth. Energy use accounts for 98 percent of CO_2 emissions.

Climate Change: A change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods.

Compressor: A compressor is used in refrigeration and cooling systems to compress vaporized refrigerant.

Cooling Degree-Days: A measure of how hot a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The cooling degree-days for a single day is the difference between that day's average temperature and 18°C if the daily average exceeds the base temperature. It is zero if the daily average is less than or equal to the base temperature. The cooling degree-days for a longer period of time is the sum of the daily cooling degree-days from the days in the period.

End-Use: Any specific activity that requires energy, e.g., refrigeration, space heating, water heating, manufacturing process, feedstocks.

Energy Efficiency Indicators: Indicators of how efficiently energy is used.

Energy Intensity: The amount of energy use per unit of activity (examples of activity measures in this report are households, floor space, passenger-kilometres, tonne-kilometres, or constant dollar value of gross domestic product by industry).

Energy Source: Any substance that supplies heat or power, e.g., petroleum, natural gas, coal, renewable energy, and electricity, including the use of a fuel as a non-energy feedstock.

Factorization Method: A method used to decompose changes in the total energy used in a sector over a certain period of time, into changes in the overall demand for that sector's output, changes in the structural composition of the sector, and changes in the energy intensity of the individual subsectors contributing to the sector's output. The factorization method used in this report is the Laspeyre index.

Fossil Fuel: Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

Framework Convention on Climate Change (FCCC): United Nations convention to address climate change (see **Climate Change**) signed by more than 150 countries at the United Nations Conference on Environment and Development, in Rio de Janeiro, June 1992. Canada became the eighth country to ratify the Convention, which entered into force on March 21, 1994, thereby committing it to work towards stabilizing greenhouse gas emissions at 1990 levels by the year 2000. In December 1997 at negotiations in Kyoto, Japan, participating countries agreed on a set of instruments and a timetable of emission reductions for the year 2010 relative to 1990. Canada committed to reduce emissions 6 percent between 2008 and 2012 relative to 1990 levels.

Gigajoule: One gigajoule equals 1 x 10^9 joules. A joule is the international unit of energy—the energy produced by a power of one watt flowing for one second. There are 3.6 million joules in one kilowatt-hour (see **Kilowatt-hour**).

Global Warming: see **Greenhouse Gas**.

Greenhouse Gas: A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chluorofluorocarbons (CFCs) and nitrogen oxides (NO_x). By far the most abundant greenhouse gas is CO_2, accounting for 70 percent of the greenhouse effect (see **Carbon Dioxide**).

Gross Domestic Product (GDP): The total value of goods and services produced by the nation's economy before deduction of depreciation charges and other allowances for capital consumption, labour and property located in Canada. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade. GDP figures are reported in real 1986 dollars.

Heating Degree-Days: A measure of how cold a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The heating degree-days for a single day is the difference between that day's average temperature and 18°C, if the daily average is below the base temperature. It is zero, if the daily average exceeds or equals the base temperature. The heating degree-days for a longer period is the sum of daily heating degree-days for days in that period.

Hydroelectric Generation: Electricity produced by an electric generator driven by a hydraulic turbine.

Interaction Effect: In the factorization method, this is a weighted average of the change in intensity and structure variables.

Kilowatt-hour (kWh): The commercial unit of electric energy equivalent to 1000 watt-hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt light bulbs burning for an hour. One kilowatt-hour is equal to 3.6 million joules (see **Watt**).

Megajoule: One megajoule equals 1×10^6 joules (see **Gigajoule**).

Megawatt-hour (MWh): One megawatt-hour equals 1×10^6 watt hours (see **Kilowatt-hour**).

Motive Power: Power provided by electric motors for driving fans, pumps, elevators or other types of equipment.

OECD: Organization for Economic Cooperation and Development

Penetration Rate: The rate at which a technology infiltrates the stock of buildings (e.g., number of refrigerators per household at a specified time).

Per Capita: Per person.

Petajoule: One petajoule equals 1 x 10^{15} joules (see **Gigajoule**).

Petroleum: A naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Primary Energy Use: Represents the total requirements for all uses of energy, including energy used by the final consumer (see **Secondary Energy Use**), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g., coal to electricity), and energy used by suppliers in providing energy to the market (e.g., pipeline fuel).

Production of Electricity: The amount of electric energy expressed in kilowatt-hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g., peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels, and environmental constraints.

Real Disposable Income Per Household: Money, in constant dollars, available to individuals per household for spending and saving after taxes and social insurance premiums, such as unemployment insurance and Canada Pension Plan premiums, have been deducted. Personal disposable income is the principal source of savings and spending in the economy.

Retrofit: Improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Secondary Energy Use: Energy used by final consumers for residential, agricultural, commercial, industrial and transportation purposes.

Sector: The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g., residential, agriculture, commercial, industrial, and transportation).

Space Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air conditioner or heat pump) or by circulating chilled water through a central-cooling or district-cooling system.

Space Heating: The use of mechanical equipment to heat all or part of a building. Includes both principal space-heating and supplementary space-heating equipment.

Structural Change: As it affects energy efficiency, structural change is a change in the shares of activity accounted for by the energy-consuming subsectors within a sector. An example of structural change is a change in product or industry mix in the industrial sector.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Vintage: The year of origin or age since the construction of a unit of capital stock (e.g., a building, a car).

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other non-cooking applications. An automatically controlled, thermally insulated vessel designed for heating water and storing heated water.

Watt (W): A measure of power, for example a 40-watt light bulb uses 40 watts of electricity (see **Kilowatt-hour**).

Weather-Adjusted Energy Intensity: A measurement of energy intensity that excludes the impact of weather.

Residential Sector

Annual Fuel Utilization Efficiency (AFUE): This is an energy rating (stated as a percentage, such as 90 percent) that indicates how efficiently a new furnace or boiler will heat a home. The higher the number, the more efficient the heating equipment.

Apartment: This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes, i.e., where the division between dwelling units is horizontal; suites in structurally converted houses; living quarters located above or in the rear of stores, restaurants, garages or other business premises; janitors' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions.

Appliances: Energy-consuming equipment used in the home for purposes other than air conditioning or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, colour televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

Dwelling: A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside. A private dwelling is one in which one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

Furnace: Space-heating equipment consisting of an enclosed chamber where fuel is burned or electrical resistance is used to heat air directly, without using steam or hot water. The warm air is for heating and is distributed throughout the house, typically by air ducts.

Heated Living Area: The area within a dwelling that is space heated.

Household: A person or a group of persons occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings. The person or persons occupying a private dwelling form a private household.

Household Size: The number of persons per household.

Mobile Home: A moveable dwelling designed and constructed to be transported (by road) on its own chassis to a site and placed on a temporary foundation such as blocks, posts or a prepared pad. It should be capable of being moved to a new location.

Single-Attached Dwelling: Each half of a semi-detached (double) house and each section of a row or terrace is defined as a single-attached dwelling. A single dwelling attached to a non-residential structure also belongs to this category.

Single-Detached Dwelling: This type of dwelling is commonly called a single house, i.e., a house containing one dwelling unit and completely separated on all sides from any other building or structure.

Thermal Characteristics: Characteristics of the building envelope in terms of its energy requirements for space heating. The building envelope is the collection of components that separate heated space from unheated space such as walls, roof, floors, windows, doors, insulation materials, etc.

Commercial Sector

Ballasts: A ballast is a device used with a fluorescent-type lamp to provide the necessary starting and operating electric conditions.

Boiler: A pressurized system in which water is vaporized to steam by heat transfer from fuel combustion. Steam thus generated may be used directly as a heating medium or converted to mechanical energy.

Floor Area (Space): The area enclosed by exterior walls of a building, including parking areas, basements, or other floors below ground level. It is measured in square metres.

Flue Gas Condensation: The liquids that are formed when exhaust gas condenses on a surface in the exhaust stream (ducts, chimneys etc.).

Liquefied Petroleum Gases (LPG): Propane and butane compose secondary LPG use. These two fuels are liquefied gases extracted from natural gas and refined petroleum products at the process plant.

Occupancy Rate: The number of occupants per square metre of floor area.

Plug Load: The electricity demand from all equipment that is plugged into electrical outlets in buildings, principally office equipment. This means it is the electricity demand other than from space conditioning, ventilation, water heating, and permanent lighting.

Industrial Sector

Auxiliary Equipment: Devices that supply energy services to the major process technologies during their operation and that are common to most industries. Auxiliary equipment fall into five categories: steam generation, lighting, heating, ventilation and air conditioning and electric motors including pumps, fans, compressors and conveyors.

Bitumen: Very heavy crude oil or tar consisting of a naturally occurring viscous mixture, mainly of hydrocarbons heavier than pentane, that may contain sulphur compounds and other minerals and that in its natural viscous state is not recoverable at a commercial rate through a well.

Building Board: Compressed paper products used as sheeting, backing for furniture, tack boards, etc. It may be used as structural material in construction.

Burner Tip Efficiency: The ratio of the useful output energy that results when a fuel is burned, to the theoretical input energy content of the fuel. Fuel efficiency for a heating fuel is less than 100 percent to the extent that heated air is used in combustion and to the extent that exhaust venting is necessary. In other applications, fuel efficiencies are less than 100 percent partly because of waste heat generation.

Capacity-Utilization Rate: The ratio of industrial production to capacity (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule).

Coke: A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke Oven Gas: Complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Impellers: The device (blade or cup) inside the pump housing that propels the fluid through the pipe. Impellers are attached to the shaft driven by the motor or other mechanical drive device.

Inorganic Chemicals Industry: Subsector of the chemicals industry represented by SIC 3711. Examples of chemical commodities produced by this sector include caustic soda, sodium chlorate, oxygen, chlorine and sulphuric acid. (see SIC)

Oilsand Upgraders: The facility at which bitumen, extracted from the oilsands, is converted to synthetic crude oil.

Organic Chemicals Industry: Subsector of the chemicals industry represented by SIC 3712. Examples of chemical commodities produced by this sector include ethylene, methyl alcohol, benzene, toluene and xylene. (see SIC)

Paperboard: Stiff paper product primarily used to make cartons and containers (cereal boxes, cracker boxes, etc.). It may be layered and used to make book covers and even furniture.

Pulping Liquor: A substance primarily made up of lignin, other wood constituents, and chemicals that are by-products of the manufacture of chemical pulp. It can be burned in a boiler to produce steam or electricity through thermal generation.

Standard Industrial Classification (SIC): A classification system that categorizes establishments into groups with similar economic activities.

Wood Wastes: Fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

Transportation Sector

Alternative Fuels: Defined to include all fuels other than conventional fuels (i.e., motor gasoline and diesel) used in road transportation.

Drivetrain: The drivetrain of a vehicle consists of the engine, transmission, differential and drive shaft.

Electronic Controls: These refer to the computerized control of engine operations to ensure that the catalytic converter is not overwhelmed by the mix of emissions it receives. Controls can affect the size of injector openings or the speed at which the fuel pump operates.

Engine Displacement: The volume of the space in the combustion chamber measured down to the top of a piston when it is furthest away from the top of the cylinder times the number of cylinders in the engine.

Horsepower: The power that a horse exerts in pulling. The unit of power equal to 746 watts.

Large Cars: Defined as cars weighing more than 1182 kilograms (2600 lb).

Light Vehicles: Includes automobiles, motorcycles, and light trucks.

Light Trucks: Defined as trucks up to 4545 kilograms (10000 lb) of gross vehicle weight.

National Transportation Act (NTA): The *National Transportation Act, 1987* was designed to promote a safe, economic, efficient and adequate network of viable and effective transportation services making the best use of all available modes of transportation at the lowest total cost. The act ensured that market forces would be the prime agents in providing viable and effective transportation services, and the regulatory powers that remained were primarily aimed at ensuring the safety of the system.

Passenger-Kilometre: The transport of one passenger over a distance of one kilometre.

Passenger-Seating Utilization to Capacity Ratio: This refers to the average number of people travelling in a vehicle compared to the average number of seating spaces in the average vehicle.

Small Cars: Defined as cars weighing up to 1182 kilograms (2600 lb).

Tonne-Kilometre: The transport of one tonne over a distance of one kilometre.

Agriculture Sector

Nurseries: An area where plants are grown for transplanting, or used as stock for budding and grafting or a place where young animals grow or are cared for.

Zero Tillage Technique: Refers to the seeding of a crop into untilled stubble by causing no more soil disturbance than opening a slit or very narrow strip of soil just enough to plant the seed. Chemical weed control is an essential part of the system. Any system in which more than 25 percent of the soil surface is disturbed is usually not considered as zero tillage.